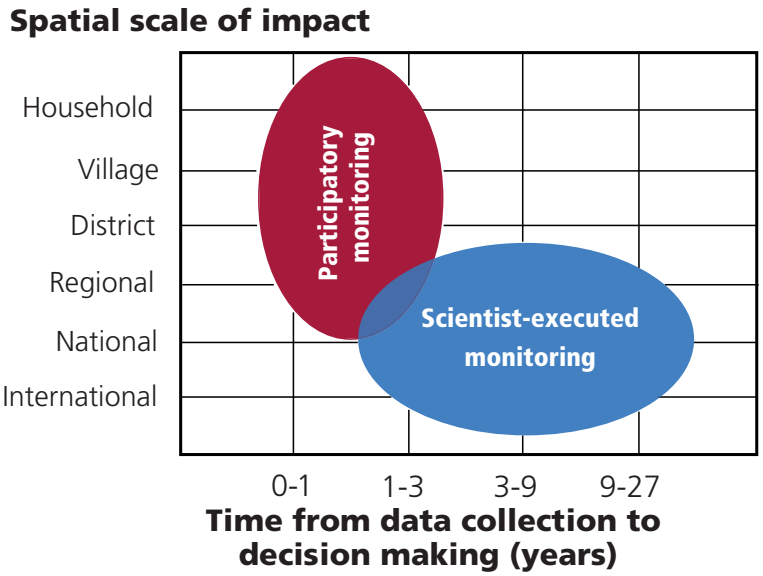
UNIVERSITY OF COPENHAGEN

Expanding the scientific basis for

How the World Can Monitor and Manage Natural Resources

Finn Danielsen



NORDECO

2016

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Denne afhandling er af Det Naturvidenskabelige Fakultet ved Københavns Universitet antaget til offentligt at forsvares for den naturvidenskabelige doktorgrad.

København, den 21. januar 2016

John Renner Hansen
Dekan, Det Naturvidenskabelige Fakultet

Forsvaret finder sted fredag den 20. maj 2016 i auditoriet, Thorvaldsensvej 40, Frederiksberg.

Front page: The effects of participatory natural resource monitoring on the scale and speed of decision-making
ISBN: 978-87-995118-7-7
Cover photo by Michael K. Poulsen

Dedicated to my family *Jonas, Line, Lasse* and *Sanne*

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Preface

Large-scale changes in natural resources are occurring at unprecedented rates. Global and local economies and potentials for development rely on the availability of clean water, arable land, fish stocks, biodiversity, energy, minerals and other renewable and non-renewable resources, and yet the availability of these resources to meet the rising expectations of a growing human population is by no means assured. My D.Sc. thesis aims to present solutions to this uncertainty.

Imagine if, by 2025:

1. Hundreds of millions of people across the planet were participating in scientific processes to observe and manage the environment and natural resources. By improving the quality and extent of natural resource monitoring and management, conflicts over resources may be reduced and sustainable livelihoods supported.

2. In communities dependent on natural resources for their livelihoods, observations by community members could inform concrete and locally-meaningful natural resource decision-making on a daily basis.

3. At the same time, the observations by community members could be communicated for analysis elsewhere (in civil society organisations, academic institutions and government agencies), expanding the scientific base and enabling new insights and better targeted land and resource decisions on the part of natural resource management bodies, encouraging a holistic approach to natural resource management.

4. A broader range of people could take part in natural resource management decisions. Community members with an interest in sustainable resource use could play a more effective and active role in promoting the sustainable use of natural resources. Citizens could to an increasing extent be acting as responsible stewards of the land and resources. Government agencies could be involving community members meaningfully in management of protected areas, enhancing local ownership and political support for the protection and sustainable use of their resources.

For this vision to come true, however, there are certain barriers that need to be removed. One of them is the widespread belief among scientists that community members in financially less wealthy countries and the Arctic are ignorant and unreliable and that only well-educated ‘experts’ can monitor and manage natural resources (at great expense).

My intents behind this document have been to provide an overview of my research concerning the opportunities of involving community members in monitoring and managing natural resources in

these parts of the world and, at the same time, to bring my contributions to the natural resource monitoring and management literature (theory and research evidence) together in a single space for those students, academics and practitioners who find themselves interested in the topic.

The present thesis has been submitted to the Faculty of Science, University of Copenhagen, in partial fulfilment of the requirements for the degree of Doctor of Science (D.Sc.).

Acknowledgments

This thesis is truly the result of teamwork. We worked in the field in ten different countries and surveyed natural resources while walking a distance equal to the circumference of the earth. The studies resulted in a total of 101 co-authors of 29 different nationalities for the 22 publications in the appendices.

Many people inspired this work. Likewise, many people were directly involved in paving the way for piloting and testing our locally-based natural resource monitoring and management approaches. They included S.W. Andersen, H. Andrianandrasana, A. Balmford, L. Barfod, C. Behe, T. Blomley, R. Bonney, T.B. Bruun, P. Constantino, H. Dissing, J. Durbin, K. Falk, K. Foldschack, T. Gardner, S. Gearheard, M. Heegaard, L.K. Holm, S. Holt, H.P. Huntington, H. Hübertz, L.T. Huong, P. Jakobsen, S. Jensen, A. Jessen, N.J. Johnson, J.P.G. Jones, N. Jørgensen, D.R. Kapijimpanga, Z.G. Larsen, M. Linddal, B. Lyberth, K. MacKinnon, J. Madsen, J.J. Madsen, S.D. Mathiesen, H. Meltofte, M. Mendoza, F. Merkel, O. Mertz, E.J. Milner-Gulland, T. Mustonen, H.S. Møller, M.R. Nielsen, H. Nøhr, S. Olsvig, A. Pullin, J.F. Rasmussen, M. Schiøtz, S. Shen, T. Sikor, K. Silvius, M. Skutsch, R. Sulyandziga, J.S. Søndergaard, M. Sørensen, I. Thaulow, M. Tengö, W. Townsend, F. Ugarte, T. Whitten, A. Yefimenko, and K. Zaunberger.

Statistics were undertaken by P.M. Jensen (VII; XI; XIV; XV; XX), C.B. Pipper (XIV), T. Adrian, S. Brofeldt, E. Rutishauser (XIII), and B. Christensen (IV). T. Enghoff and J. Eilenberg advised on software and thesis structure. A.G. Foldschack managed the project funds. B. Rubæk prepared the artwork. T. Nielsen designed the layout. E.D. Bolton proofread the language. Comments to the introduction were provided by N. Burgess, M. Enghoff, J. Fjeldså, M. Funder, S. Hvalkof, P.M. Jensen, and M.K. Poulsen.

My thesis is only possible because of the fruitful discussions and exchanges of experience I have had on a daily basis for many years with T. Adrian, S. Brofeldt, N. Burgess, M. Enghoff, J. Fjeldså, M. Funder, S. Hvalkof, A.E. Jensen, P.M. Jensen, S. Johnsen, Å. Jørgensen, N. Levermann, K. Pirhofer, M.K. Poulsen, T. Skielboe, E. Topp-Jørgensen and I. Theilade, for which I am exceptionally grateful.

For economic support, I thank Danida; European Commission (‘BEST’ and 7th Framework Research Programme); Global Environment Facility; Greenland Department of Fisheries, Hunting and Agriculture; Nordic Council of Ministers; Nordic Foundation for Development and Ecology; Philippine Department of Environment and Natural Resources, Biodiversity Management Bureau; Swiss Development Cooperation; The World Bank; and University of Copenhagen.

English Summary

This D.Sc. thesis presents research into the theory, practice, application and results of 'citizen science' as applied in the developing world (Africa, South East Asia, Latin America) and in the Arctic (Greenland). It focuses on the opportunities of engaging local community members in natural resource monitoring and management in those areas of the world where 'citizen science' was previously widely believed to be impossible. Using theoretical, experimental and real-world case examples, the thesis defines the existing types of natural resource monitoring system and examines the potential of locally-based approaches: (i) to provide high-quality information, (ii) to empower local people in natural resource management, and (iii) to impact on livelihood and biodiversity. The main results are summarized below.

1. Development of typology

A typology of monitoring approaches is proposed for the natural world. Five categories of monitoring are described, ranging from efforts where monitoring is undertaken solely by professional researchers to entirely local efforts with all the work undertaken by local people. This continuum of monitoring approaches largely mirrors the devolution of management responsibility in different approaches to natural resource management.

2. Quality of information

In vegetation plots in five major forest types, community members' measurements of tree circumference were of comparative quality to that of trained scientists. Likewise, during foot patrols at study sites across all three tropical continents, experienced forest product collectors with limited formal reading and writing skills produced results similar to those of trained scientists on the status of and trends in species and natural resources. Moreover, in two case examples, findings from community-led focus group discussions on the abundance of natural resources corresponded closely with similar results from trained scientists' field surveys.

3. Potential for empowerment

The awareness about the opportunities that local communities now have for being 'heard' can create the motivation that is needed for the community members to demonstrate their ability to act and themselves monitor the state of their environment and make responsible decisions. Natural resource monitoring where community members collect, process and interpret data and where the monitoring activities are integrated with existing natural resource governance systems, can contribute to political, social and economic dimensions of empowerment of the community members in natural resource management.

4. Livelihood and biodiversity impacts

Whereas scientists may still play a major role in influencing international and national conventions and regulations, locally-based approaches to natural resource monitoring can be more effective when it comes to generating local natural resource management interventions with the potential to

impact on livelihood and biodiversity. Decisions from locally-based approaches to natural resource monitoring tend to be taken at the local, operational levels of resource management, where they involve the people who face the daily consequences of environmental changes.

5. Future potential

Locally-based approaches to natural resource monitoring have considerable potential for improving understanding of environmental changes as well as for improving the management of natural resources. 'Citizen scientists' may be the only feasible way to understand the changes on the planet with sufficiently dense sampling to build credible models of those factors that cannot be measured by remote sensing. This includes aspects of species abundance change, habitat use and degradation, local-use impacts on biomass and the ecological structure of harvested species and their ecosystems (on land and in the sea), the intensity of pressures on nature, and the introduction of new species. Thematically, locally-based approaches to natural resource monitoring have considerable potential: (i) to connect environmental performance with payment schemes, (ii) in efforts to bring indigenous and local knowledge systems into the science–policy interface, (iii) to inform resource management in rapidly changing environments such as the Arctic, and (iv) in efforts to link international environmental agreements to decision-making in the 'real world'.

6. Further study needs

Further research could substantially contribute to transform the way the world tracks changes in species and other natural resources on earth. Five key areas of research are proposed, from social theory on why people participate in these schemes, through analysis of 'big data', to considerations of accuracy and the technological developments necessary to make 'citizen science' approaches and data capture and analysis available to all – in developed and developing nations.

Key words: adaptive management, citizen science, crowd-sourcing, natural resource management, observing system, participation.

Dansk Sammendrag

Afhandlingen præsenterer forskning i 'citizen science' teori, praksis, applikationer og resultater. I afhandlingen beskrives mulighederne for at engagere den lokale befolkning i monitering, dokumentation og forvaltning af naturressourcer i Arktis (Grønland) og i områder i Afrika, Sydøstasien og Latinamerika, hvor man tidligere har troet, at 'citizen science' ikke er mulig. I afhandlingen bruges teoretiske eksempler, eksperimenter og eksempler fra den virkelige verden. Først defineres de eksisterende former for naturovervågning. Dernæst præsenteres mulighederne for, at naturovervågning, der inddrager den lokale befolkning, kan: (i) generere viden af høj kvalitet, (ii) styrke borgernes rolle i forvaltningen af naturressourcer, (iii) forbedre menneskers levebrød og sikre et områdes biodiversitet. Nedenfor beskrives afhandlingens vigtigste resultater.

1. Udvikling af typologi
I afhandlingen defineres et spektrum af måder, hvorpå man kan monitere naturressourcer. Fem kategorier af moniteringssystemer beskrives, fra systemer, hvor naturovervågningen foretages af professionelle forskere alene – til helt lokale initiativer, hvor alle dele af moniteringen udføres af de lokale borgere på egen hånd. Dette kontinuum af måder, hvorpå man kan monitere, afspejler i store træk uddelegeringen af ansvaret for beslutninger i forskellige former for forvaltning af naturressourcer.

2. Kvaliteten af de lokales viden
I vegetationsplot i fem undersøgte skovtyper var de lokale menneskers målinger af træernes omkreds af samme kvalitet som trænede forskeres målinger. Under patruljer i skoven til fods på lokaliteter på alle tre tropiske kontinenter registrerede borgere, der havde ringe læse- og skrive-kundskaber men stor erfaring med skovressourcer, status på og ændringer i forekomsten af arter og naturressourcer, der nøje svarer til trænede forskeres feltundersøgelser. I to case studier var status for forekomsten af naturressourcer baseret på fokusgrupper med erfarne naturbrugere i god overensstemmelse med trænede forskeres feltundersøgelser.

3. Styrkelse af de lokale samfund
Opmærksomheden omkring de muligheder, som de lokale samfund i dag har for at blive 'hørt', kan skabe den motivation, der skal til, for at de lokale mennesker demonstrerer deres evner til at handle og til selv at overvåge deres naturmiljø og tage ansvarlige beslutninger. Monitering af naturressourcer, hvor lokale borgere indsamler, bearbejder og fortolker deres observationer, og hvor moniteringen er integreret med forvaltningen af naturressourcerne, kan bidrage til styrkelse af borgernes rolle i forvaltningen af naturressourcer, både politisk, socialt og økonomisk.

4. Forbedrede levebrød og sikret biodiversitet
Hvor forskere stadig kan spille en stor rolle ved at have indflydelse på internationale konventioner og national lovgivning, så kan monitering af naturressourcer, hvor den lokale befolkning inddrages, være mere effektiv, når målet er at fremme lokale forvaltningsbeslutninger, der potentielt kan

forbedre de lokales levebrød og sikre et områdes biologiske mangfoldighed. Beslutninger om forvaltning af naturressourcer på baggrund af den lokale befolknings observationer træffes ofte på lokalt niveau, hvor beslutningerne involverer de mennesker, der er direkte udsat for effekterne af miljøændringer.

5. Fremtidigt potentiale

Naturovervågning, der inddrager den lokale befolkning, har stort potentiale for at forbedre forståelsen af miljøændringer og for at styrke forvaltningen af naturressourcer. Systematisk brug af erfarne borgeres observationer er måske den eneste mulighed, der findes, for at opnå forståelse af ændringer på jorden i en tilstrækkelig fin opløsning til at opbygge troværdige modeller af de miljøforhold, der ikke kan moniteres fra satellitter. Det kan f.eks. være ændringer i arters forekomst, habitatbrug og habitatdegradering, påvirkninger fra lokal ressource anvendelse på biomasse og på den økologiske struktur af høstede arter og deres økosystemer (både på land og i havet), intensiteten af pres på naturen, og introduktionen af nye arter. Tematisk har naturovervågning, der inddrager den lokale befolkning, et stort potentiale: (i) i 'payment for ecosystem services' programmer, (ii) i bestræbelserne på at bringe oprindelige og lokale videnssystemer ind i grænsefladen mellem videnskab og politik, (iii) til at rådgive forvaltere af naturressourcer i miljøer, der hurtigt ændrer sig såsom i Arktis, og (iv) i bestræbelserne på at forbinde internationale miljøaftaler med beslutningsprocesser i den 'virkelige verden'.

6. Yderligere undersøgelser

Yderligere forskning kan bidrage væsentligt til at forbedre den måde, hvorpå verden følger med i ændringer i arter og andre naturressourcer på jorden. Der foreslås fem centrale områder for forskning, fra forskning i sociale teorier om, hvorfor folk deltager i 'citizen science', gennem analyse af 'big data', til forhold omkring nøjagtigheden og den teknologiske udvikling, der er nødvendig for at gøre borger-baseret data-indsamling og fortolkning tilgængelig for alle – både i de udviklede lande og i udviklingslandene.

Nøgleord: adaptiv forvaltning, citizen science, crowd-sourcing, deltagelse, naturressource-forvaltning, observationssystemer.

List of included publications

Spectrum of approaches to Natural Resource Monitoring

I **Danielsen**, **F**., Balete, D.S., Poulsen, M.K., Enghoff, M., Nozawa, C.M. and Jensen, A.E. 2000. A simple system for monitoring biodiversity in protected areas of a developing country. *Biodiversity and Conservation* 9: 1671–1705.

II **Danielsen**, **F**., Mendoza, M.M., Alviola, P., Balete, D.S., Enghoff, M., Poulsen, M.K. and Jensen, A.E. 2003. Biodiversity monitoring in developing countries: what are we trying to achieve? *Oryx* 37: 407–409.

III **Danielsen**, **F**., Mendoza, M.M., Tagtag, A., Alviola, P., Balete, D.S., Enghoff, M., Poulsen, M.K. and Jensen, A.E. 2003. On participatory biodiversity monitoring and its applicability – a reply to Yoccoz et al. and Rodríguez. *Oryx* 37: 412.

IV **Danielsen**, **F**., Burgess, N.D. and Balmford, A. 2005. Monitoring matters: examining the potential of locally-based approaches. *Biodiversity and Conservation* 14: 2507–2542.

V Mascia, M.B., Pailler, S., Thieme, M., Rowe, A., Bottrill, M.C., **Danielsen**, **F**., Geldmann, J., Naidoo, R., Pullin, A. and Burgess, N.D. 2014. Commonalities and complementarities among approaches to conservation monitoring and evaluation. *Biological Conservation* 169: 258–267.

VI **Danielsen**, **F**., Burgess, N.D., Balmford, A., Donald, P.F., Funder, M., Jones, J.P.G., Alviola, P., Balete, D.S., Blomley, T., Brashares, J., Child, B., Enghoff, M., Fjeldså, J., Holt, S., Hübertz, H., Jensen, A.E., Jensen, P.M., Massao, J., Mendoza, M.M., Ngaga, Y., Poulsen, M.K., Rueda, R., Sam, M., Skielboe, T., Stuart-Hill, G., Topp-Jørgensen, E. and Yonten, D. 2009. Local participation in natural resource monitoring: a characterization of approaches. *Conservation Biology* 23: 31–42.

VII **Danielsen**, **F**., Pirhofer-Walzl, K., Adrian, T., Kapijimpanga, D., Burgess, N.D., Jensen, P.M., Bonney, R., Funder, M., Landa, A., Levermann, N. and Madsen, J. 2014. Linking public participation in scientific research to the indicators and needs of international environmental agreements. *Conservation Letters* 7: 12–24.

Empowering local people through Natural Resource Monitoring

VIII **Danielsen**, **F**., Burgess, N., Funder, M., Blomley, T., Brashares, J., Akida, A., Jensen, A., Mendoza, M., Stuart-Hill, G., Poulsen, M.K., Ramadhani, H., Sam, M.K. and Topp-Jørgensen, E. 2010. Taking stock of nature in species-rich but economically poor areas: An emerging discipline of locally-based monitoring. Pp. 88–112 in: *Taking Stock of Nature* (Ed. A. Lawrence). Cambridge Univ. Press, UK.

IX Funder, M., **Danielsen**, **F**., Ngaga, Y., Nielsen, M.R. and Poulsen, M.K. 2013. Reshaping conservation: The social dynamics of participatory monitoring in Tanzania's community-managed forests. *Conservation and Society* 11: 218–232.

Quality of information from locally-based approaches to Natural Resource Monitoring

X **Danielsen**, **F**., Topp-Jørgensen, E., Levermann, N., Løvstrøm, P., Schiøtz, M., Enghoff, M. and Jakobsen, P. 2014. Counting what counts: using local knowledge to improve Arctic resource management. *Polar Geography* 37: 69–91.

XI **Danielsen**, **F**., Skutsch, M., Burgess, N.D., Jensen, P.M., Andrianandrasana, H., Karky, B., Lewis, R., Lovett, J.C., Massao, J., Ngaga, Y., Phartiyal, P., Poulsen, M.K., Singh, S.P., Solis, S., Sørensen, M., Tewari, A., Young, R. and Zahabu, E. 2011. At the heart of REDD+: a role for local people in monitoring forests? *Conservation Letters* 4: 158–167 (with cover page).

XII Skutsch, M., Zahabu, E., Karky, B.S. and **Danielsen**, **F**. 2011. The costs and reliability of forest carbon monitoring by communities. Pp. 73–81 in: *Community Forest Monitoring for the Carbon Market* (Ed. M. Skutsch). Earthscan, London.

XIII **Danielsen**, **F**., Adrian, T., Brofeldt, S., Noordwijk, M. van, Poulsen, M.K, Rahayu, S., Rutishauser, E., Theilade, I., Widayati, A., An, N.T., Bang, T.N., Budiman, A., Enghoff, M., Jensen, A.E., Kurniawan, Y., Li, Q., Mingxu, Z., Schmidt-Vogt, D., Prixa, S., Thoumtone, V., Warta, Z. and Burgess, N. 2013. Community monitoring for REDD+: international promises and field realities. *Ecology and Society* 18(3): 41.

XIV **Danielsen**, **F**., Jensen, P.M., Burgess, N.D., Altamirano, R., Alviola, P.A., Andrianandrasana, H., Brashares, J.S., Burton, A.C., Coronado, I., Corpuz, N., Enghoff, M., Fjeldså, J., Funder, M., Holt, S., Hübertz, H., Jensen, A.E., Lewis, R., Massao, J., Mendoza, M.M., Ngaga, Y., Pipper, C.B., Poulsen, M.K., Rueda, R.M., Sam, M., Skielboe, T., Sørensen, M. and Young, R. 2014. A multi-country assessment of tropical resource monitoring by local communities. *BioScience* 64: 236–251.

XV **Danielsen**, **F**., Jensen, P.M., Burgess, N.D., Coronado, I., Holt, S., Poulsen, M.K., Rueda, R.M., Skielboe, T., Enghoff, M., Hemmingsen, L.H., Sørensen, M. and Pirhofer-Walzl, K. 2014. Testing focus groups as a tool for connecting indigenous and local knowledge on abundance of natural resources with science-based land management systems. *Conservation Letters* 7: 380–389.

Livelihood and biodiversity impacts of Natural Resource Monitoring

XVI **Danielsen**, **F**., Burgess, N. and Topp-Jørgensen, E. 2007. Native Knowledge. *Science* www.sciencemag.org/cgi/eletters/315/5818/1518.

XVII Huntington, H.P., **Danielsen**, **F**., Enghoff, M., Levermann, N., Løvstrøm, P., Schiøtz, M., Svoboda, M. and Topp-Jørgensen, E. 2013. Conservation through community involvement. Pp. 644–647 in: *Arctic Biodiversity Assessment. Status and trends in Arctic biodiversity* (Ed. H. Meltofte). Conservation of Arctic Flora and Fauna, Akureyi, Iceland.

XVIII **Danielsen**, **F**., Mendoza, M.M., Tagtag, A., Alviola, P.A., Balete, D.S., Jensen, A.E., Enghoff, M. and Poulsen, M.K. 2007. Increasing conservation management action by involving local people in natural resource monitoring. *Ambio* 36: 566–570.

XIX **Danielsen**, **F**., Jensen, A.E., Alviola, P.A., Balete, D.S., Mendoza, M.M., Tagtag, A., Custodio, C. and Enghoff, M. 2005. Does monitoring matter? A quantitative assessment of management decisions from locally-based monitoring of protected areas. *Biodiversity and Conservation* 14: 2633–2652.

XX **Danielsen**, **F**., Burgess, N.D., Jensen, P.M. and Pirhofer-Walzl, K. 2010. Environmental monitoring: the scale and speed of implementation varies according to the degree of people's involvement. *Journal of Applied Ecology* 47: 1166–1168 (with cover page and podcast interview; http://bdown.astream.com/jpe/danielsen.mp3).

Future potential of locally-based approaches to Natural Resource Monitoring

XXI Gardner, T.A., Burgess, N.D., Aguilar-Amuchastegui, N., Barlow, J., Berenguer, E., Clements, T., **Danielsen**, **F**., Ferreira, J., Foden, W., Kapos, V., Khan, S.M., Lees, A.C., Parry, L., Roman-Cuesta, R.M., Schmitt, C.B., Strange, N., Theilade, I. and Vieira, I.C.G. 2012. A framework for integrating biodiversity concerns into national REDD+ programmes. *Biological Conservation* 154: 61–71.

XXII **Danielsen**, **F**., Balete, D., Poulsen, M.K., Enghoff, M., Palaganas, V., Nozawa, C. and Jensen, A.E. 2001. *Biodiversity Monitoring System Manual for Protected Areas*. The World Bank, Danida, and Department of Environment and Natural Resource, Manila and NORDECO, Copenhagen. 1–78 pp. 2nd edition.

Chapter 1.

Introduction

1.1 Background

Human knowledge on the status and trends of natural resources, ecosystem services and species on earth is limited (Butchart et al. 2010; Beddington et al. 2011; Jetz et al. 2012; Joppa et al. 2013). Global environmental assessments synthesize this limited data (CBD 2010; UNEP 2010; WWF 2012), which is then used in decision-making. There is a serious risk that decisions are poorly targeted and not addressing critical needs.

Over the past 100 years, science has been the preserve of 'experts'. It is increasingly recognized that local community members who may not qualify as experts in conventional terms can be very knowledgeable about local resources (Devictor et al. 2010; Cerdán et al. 2012). Moreover, local community members have an important role in the sustainable use of natural resources (Hayes 2006; Nelson & Chomitz 2011; Persha et al. 2011; Mace 2014). The remarkable rise of technology and, in particular, mobile devices and social media, which have penetrated across the world (now also in developing regions), opens up the possibility for hundreds of millions of people to participate in scientific processes, and to gather information and obtain results that are both locally and globally relevant and potentially transformational in scope (Folke 2004; Perrings et al. 2011; Turnhout et al. 2012; Hsu et al. 2014). Expanding the scientific base to include community members or 'citizen scientists' would provide multiple, fine-scaled data points on the changes in the natural resources of the planet – allowing credible models to be built on factors that cannot be measured by remote sensing (Huntington 2011; Dickinson & Bonney 2012; Haklay 2013; Cooper et al. 2014; Mitchard et al. 2014). This includes species abundance changes, habitat use and degradation, local use of biomass and hunted species, local pressures on nature, and introductions of species.

In the Nordic Foundation for Development and Ecology (NORDECO, Copenhagen) and at Faculty of Science, University of Copenhagen, we have worked together with communities, government agencies and civil society organizations to enhance local capacity for the monitoring and management of natural resources. Alongside this, I have addressed the theory and practice of 'citizen science' (Bonney et al. 2009; 2014) as applied to environmental change questions, and implemented in the developing (Africa, South East Asia, Latin America) and Arctic (Greenland) worlds. Whereas by citizens I mean 'local community members' in general, my research has focused on the possibilities of engaging citizens in natural resource monitoring and management in the world's financially less wealthy countries and the Arctic, where there has previously been minimal attention to 'citizen science'.

This thesis presents the main results of my past 20 years of research. Firstly, on our typology of natural resource monitoring systems, with varying degrees of relative contributions of local stakeholders and professional researchers (Chapter 2). Secondly, on the empowerment of community members (Chapter 3), the quality of information (Chapter 4), and the impacts on livelihood and biodiversity (Chapter 5) of community members' monitoring of natural resources. Finally, I discuss the potential of the different approaches to natural resource monitoring (Chapter 6) and offer recommendations for future research (Chapter 7). Appendices I-XXII are the publications included in my thesis. In the text, they are referred to as roman numerals. The numbering of appendices follows the chapters as much as possible.

When I began this research, the prevailing view among natural scientists was that in developing countries and the Arctic only well-educated 'experts' could monitor natural resources (Shepard et al. 2001; Sejersen 2003; Sheil & Lawrence 2004; McComb et al. 2010; Huntington 2011). Community members were widely viewed as ignorant and unreliable. My suggestion for a complementary approach that involved community members in the monitoring of natural resources was therefore met with considerable resistance.

A different view is now emerging (Lawrence 2010; Singh & Milner-Gulland 2011; Skutsch 2011; Bonney et al. 2014; Pulsifer et al. 2014; Tengö et al. 2014; Vincent & Harris 2014), perhaps because of the documentation that I and others have put together. My findings have been used in reports on global development (World Bank 2010) and they have appeared in eight textbooks (Spellerberg 2005; Milner-Gulland & Rowcliffe 2007; Buckley 2009; Gardner 2010; McComb et al. 2010; Sodhi and Ehrlich 2010; Maschinski & Haskins 2012; Jones et al. 2013). Our photos of citizen scientists from Africa and the Arctic have graced the cover pages of two journals (XI; XX). The publications in my thesis have been presented at meetings (Nobel Peace Prize Forum 2014), they have been widely cited in the media (Kinver 2013; Ecological Society of America 2014), and they have been used by hundreds of practitioners and scientists (>1,000 citations on Google Scholar, 2014). My papers appear on the website of the United Nations Framework Convention on Climate Change (UNFCCC) and they have contributed to shape the policies of this Convention (Government of Madagascar 2008; European Community 2009). There are locally-based approaches to natural resource monitoring in operation on all the inhabited continents.

1.2 How did we get here? Our field experiences

My interest in a better understanding of citizen science as applied to environmental change questions emanates from field experiences and natural science considerations (this chapter) as well as from social science considerations (Chapter 1.3). In 1994, the Philippine Government decided to develop a natural resource monitoring system for protected areas of the country. The Government and staff of The World Bank, involved with managing natural resource cooperation with the Philippines, asked my colleagues and myself at NORDECO, for assistance. I therefore reviewed the scientific literature and existing practice in natural resource monitoring in developing regions (I), finding that basic assumptions for quantitative recording of natural resources had already been described in the literature (e.g., Wilson et al. 1996; Dallmeier & Comiskey 1998; Margules et al.

1998; Thompson et al. 1998; Bibby et al. 2000), and that the broader concepts of natural resource monitoring had also been outlined (e.g., Noss 1990; Brown & Wyckoff-Baird 1992; World Bank 1992; Harmon 1994; Kremen et al. 1994; Wangwacharakul et al. 1996). However, few suggestions had been made as to how these could be meaningfully translated into a developing region context (e.g., Fuller 1998; Kremen et al. 1998; Margoluis & Salafsky 1998; World Bank 1998; Hellier et al. 1999; Terborgh & Davenport 2002; Bull 2005), particularly given the inherent tensions between standardization of data, facility of collection and ease of analysis (IBAMA 1998).

Initial monitoring efforts in developing countries had tended to follow the standards used in the Western world (I). Compared with the West, developing regions have very limited institutional and professional capacity and financial resources available. Furthermore, most rural areas in developing regions serve to meet the daily subsistence requirements of rural people (Saberwal & Kothari 1996). It was therefore unlikely that monitoring systems developed in other parts of the world would be suited to developing regions.

For example, many monitoring systems in tropical forests included the establishment of permanent vegetation plots where all plants above a certain size would be identified to species and measured, for instance every 5 years (Condit et al. 1995; 1999). Such monitoring can generate data for rigorous hypothesis testing and provide important scientific evidence. However, since the frequency of data collection is low and limited data is collected on the use of resources, such an exercise rarely provides any input to management (I). For natural resource management purposes, rural areas in developing regions need monitoring that is realistic and, at the same time, useful for guidance rather than that which is ideally required for in-depth studies of how community structure and species richness are affected by different environmental changes.

Together with other researchers I therefore set out to develop a simple and cost-effective natural resource monitoring system, which:

1. Requires a minimum of training and education on the part of the government staff,
2. Requires little equipment and financial resources,
3. Seeks to encourage the participation of local communities in natural resource management,
4. Strengthens existing local systems for monitoring and managing natural resources.

The aim of the monitoring system in Philippine protected areas is to ensure better management and the involvement of local people rather than data-based falsification of scientific hypotheses concerning variation in natural resource values (I; XXII). The monitoring system was developed for use in the country's protected areas. In developing regions, in particular, most natural resource management decisions are taken at a local level (e.g. Groombridge & Jenkins 1996), and the system thus focuses on monitoring at the level of the single protected area (or management unit). The monitoring system was designed and tested in three protected areas and the government then decided to embark on large-scale implementation of the system in all the country's protected areas (XXII, last page).

What are the key elements of the Philippine monitoring system? This monitoring system was intended to identify trends in important natural resource assets and to use these trends to guide management action in protected areas. It was also intended to enhance the participation of protected-area communities in managing the protected area (I; VI). Data were collected by government rangers and volunteer community members. By allowing rangers to participate in field assessments, the scheme encouraged them to get into the field and improved their capacity for management. In each protected area, monitoring focused on a list of 10–15 taxa and 5–10 signs of resource use, selected by local community members together with protected-area staff. Data were collected every 3 months. Data interpretation was undertaken locally by the protected-area staff and community members, and a short report was presented every quarter to the Management Council of each protected area. The report included the data set, a list of important observations of changes in species and resource use, and a list of proposed management interventions with a description of the issue identified, the location and the proposed action to be taken by the protected-area council (XIX). Foreign support ceased in 2001 but the scheme continues at most of the sites where it was established. The government has promoted the scheme as a standard management tool in protected areas, and it has spread to new sites. In 2012, there were 435 community member participants in the scheme (A.E. Jensen *in litt.* 2013).

The Philippine natural resource monitoring system was compared with published criteria for making forest natural resource monitoring systems capable of providing unequivocal answers (Margules et al. 1998). For forest biodiversity monitoring programs to be able to provide unequivocal answers, Margules et al. (1998) identified six important elements:

1. Controls in areas with no human activity,
2. Replication in sampling to account for spatial heterogeneity and random variation,
3. Knowledge of conditions before human activity began,
4. Environmental stratification to capture the habitat preferences of specialized species and facilitate analyses of the responses of less abundant species,
5. A sufficient period of monitoring to establish human use effects and distinguish them from climatic fluctuations or other episodic events, and
6. Replication at more than one location to avoid location-specific phenomena.

How did the Philippine monitoring system approach these elements? Controls in unused or largely unused areas (1) are in practice not made because undisturbed forest areas are very difficult to access. Replication of sampling (2) is undertaken by applying the methods on several sites in each protected area. The monitoring system does not establish knowledge of pre-human use conditions (3) since this would be logistically very difficult and human use of Philippine protected areas cannot be regulated as in an experiment. Environmental stratification (4) is conducted, the monitoring system is expected to continue for a long period (5), and the monitoring system is replicated in several protected areas (6).

In the Philippine system, not all the elements that are desirable for monitoring programs were thus included but it did demonstrate what monitoring can be undertaken in practice by protected-area

staff and local communities. Many attempts to establish natural resource monitoring systems in developing regions have run into serious trouble because the systems were too large and complicated (Sheil 2001). The Philippine natural resource monitoring system was developed bearing the typical problems of developing regions in mind, including those relating to high numbers of species, incomplete taxonomic knowledge, few economic resources and the large total size of protected areas (I). This monitoring system was considered a feasible minimum starting point, which could evolve further over time as more resources and skilled people become available to manage and monitor biodiversity. As long as the procedures for the methods are continued on the same sites, development of the system does not significantly violate the assumption for monitoring that quality and reliability of data sampling remain unchanged.

The ability of this monitoring system to detect trends in abundance of species and resource uses (i.e. to distinguish a situation different from the null hypothesis) could be strengthened by using more standardized methods e.g. territory mapping of birds (Bibby et al. 2000), arthropod protocols (Coddington et al. 1991) and permanent forest inventory plots (Alder & Synnott 1992). However, while more standardized methods can be valuable tools, we found that their usefulness in practice will be constrained by:

1. The shortage of trained field scientists, support staff and facilities,
2. The small proportion of taxa described and sufficiently known to make them useful in applied programs, and
3. The lack of identification manuals for many species groups in developing regions.

Prompted by studying the established 'state-of-the-art' of natural resource monitoring systems as it was expressed in an authoritative review (Yoccoz et al. 2001), I led a call for the attention to the gap between ideals and realities with respect to monitoring systems in developing regions (II; III). I emphasized that natural resource monitoring programs in developing regions frequently collapse when the donor funding stopped and were often unable to contribute to natural resource management because they were ineffective in integrating information into decision-making. I instead suggested that methods should be simple, cost-effective and possible to sustain and where the meaning of the monitoring can be grasped by local people who, in practice are the custodians of many areas. Likewise, I suggested that methods are focused on authorities supporting local people to enhance and formalize the existing, informal monitoring already carried out in many areas. Our call for attention was met with interest (Yoccoz et al. 2003) but it was suggested that the Philippine experiences may be context-dependent and not applicable elsewhere (Rodríguez 2003).

To explore the extent to which the field experiences with locally-based approaches to natural resource monitoring in the Philippines were applicable elsewhere, I took initiative to invite representatives of other existing local monitoring initiatives in terrestrial, marine and freshwater ecosystems on all three tropical continents to exchange lessons at a symposium in Denmark. The symposium included 15 case studies that involved >1,500 community members in 13 countries. The 15 case studies formed the backbone of a 320-page special issue of *Biodiversity and Conservation* (IV; XIX).

One of the key conclusions of our discussions of field experiences across the 15 case studies was that local approaches have the potential to be low cost, rapid, locally-relevant and capable of building capacity among the local constituents. However, we found that further quantitative comparisons of the findings of locally-based and "professional" monitoring were badly needed, especially in developing countries, and in circumstances where data-gatherers have received little or no formal scientific education (IV). We did not think that every locally-based scheme needed to be calibrated against a "professional" method – this would be logistically impractical, unaffordable, and would imply widespread distrust of local communities. However, we suggested that all local methods needed careful and well-documented checking against broadly-accepted techniques, across a range of local contexts. Unless this costly and time-demanding task was done, we believed there would always be a concern that, however well-intentioned, management interventions derived from local monitoring might in some cases be directed towards inappropriate targets (Holt et al. 2013).

The conclusions from the symposium guided my research in the ensuing years. I led comparisons of field results from three local methods: community member vegetation plots (XI; XII; XIII), patrol records (XIV), and focus group discussions (XV) with findings from closely similar field methods used by trained scientists. I also studied whether locally-based monitoring is an effective resource management tool when compared with conventional methods (XVIII; XX), the social dynamics involved (IX), and the potential of local approaches in the Arctic (X; XVII).

1.3 Social science considerations

When monitoring methods are focused on authorities supporting local people to enhance and formalize the existing, informal monitoring already carried out in many areas, the monitoring can function as a 'vehicle' for continual engagement among communities, authorities and researchers, resembling Model 5 in Fig. 1. Independent of my work, Reid et al. (2009) developed this model when attempting to balance pastoral livelihoods and wildlife conservation in savannas of East Africa. The model describes the engagement' among community members, policy makers, and researchers on the basis of the experiences of Reid and his colleagues with a range of approaches to link knowledge with action. They originally started with the use of Model 1 (Fig. 1), where community members participated as field guides and interview subjects. In this model, the research questions were largely academic but with an eye to influence science and policy over time. Reid and his colleagues gradually became more actively involved with policy makers and communities in an effort to create scientific information more relevant to their needs. They first directed their work toward issues of concern for policy makers and community members as shown in Model 2, and then did so more fully by consulting communities and policy makers on problems at the outset of the research (Model 3). Some members of their team connected Models 2 and 3, identifying problems together with communities or policy makers, feeding initial research findings back to communities and interpreting these findings together as shown in Model 4. This progression then evolved further into the 'model of continual engagement' through facilitation and further integration – in aspects of the information generation, interpretation, and action – of community member 'producers' and 'consumers' of information (Model 5).

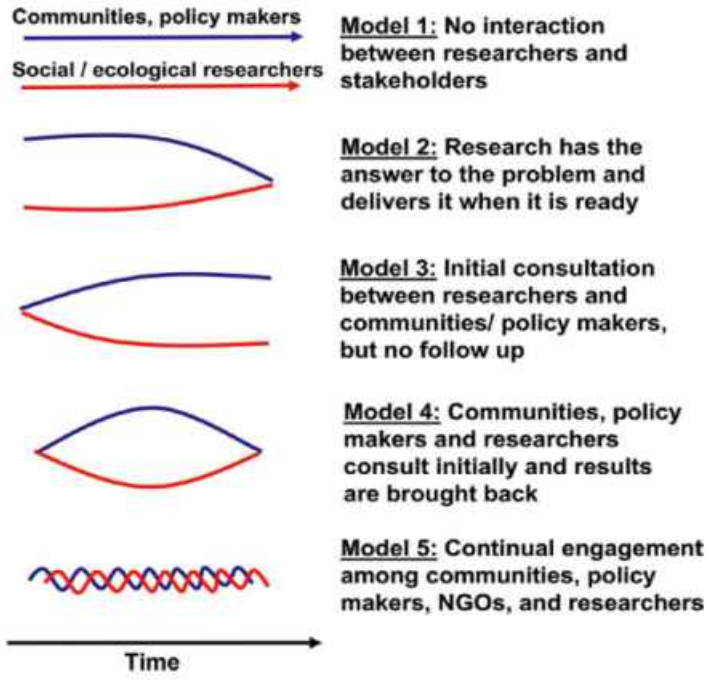

Figure 1. Schematic model of approaches to link natural resource knowledge with action, ranging from no interaction between researchers and stakeholders (Model 1) – to continual engagement among communities, policy makers, and researchers (Model 5). Developed by Reid et al. (2009) independent of my work. Reprinted with permission.

This evolution of approaches to link natural resource knowledge with action, eloquently described by Reid et al. (2009), corresponds with the experiences I had in the Philippines and that led us to develop the locally-based Philippine monitoring system (I).

From a theoretical social science perspective, my interest in obtaining an understanding of citizen science as applied to issues of environmental change originated from the potential linkages between (1) citizen involvement in monitoring, (2) 'ownership' of natural resource monitoring and management, and (3) environmentally-sustainable resource use. I will discuss this below.

I initially focused on *ownership* based on the view that it was important to get local people to participate and be committed in relation to monitoring and conservation – i.e. with conservation as the key objective. In the process, I however learned that local participation in monitoring may also contribute to other aspects of empowerment beyond ownership.

The idea that ownership can lead to responsible behavior is not new. When Aristotle and Plato discussed the relation between property and virtue c. 330 years Before the Common Era, Aristotle argued that ownership promotes prudence and responsibility (Everson 1988): '(W)hen everyone has a distinct interest, men will not complain of one another, and they will make more progress, because everyone will be attending to his own business' (Aristotle, The Politics, 1263a). Ownership may be tangible in terms of private or collective rights over land and resources, as was the focus of the discussions of Aristotle and Plato, or it may less tangible as in the feeling that something is one's

own even if legal ownership of the thing is actually conferred on somebody else (Furby 1978). Feelings of ownership can likewise develop around a variety of objects, both material *and* non-material (Baer & Brown 2012).

In the behavioral and organisational sciences, psychologists have conceptually-defined feelings of ownership (i.e. psychological ownership) as being 'the state in which individuals feel as though the target of ownership or a piece of that target is 'theirs'' (Pierce et al. 2001; 2003). Feelings of ownership are not necessarily a good or a bad thing, they are merely 'part of the human condition' (Pierce & Jussila 2011).

I cannot do better than summarize the work of Professor Jon L. Pierce and his co-workers. They have suggested that people develop feelings of ownership for a target in three ways, through having control over the target, having intimate knowledge of the target, and investing the self in the target (Box 1).

Box 1. Three ways that people develop feelings of ownership (from Pierce et al. 2003 and Pierce & Jussila 2011; summary with the original references included).

1. Controlling the ownership target. Objects that can be controlled come to be regarded as part of the self (e.g. Sartre 1943/1969). In contrast, those objects which are controlled by others – or those which simply cannot be controlled – are not considered a part of the individual's sense of self (Lewis & Brook 1974; Seligman 1975).

2. Coming to intimately know the target. When an object is very well known, it becomes part of the self. For instance, James (1890) suggested that, through a living relationship with objects, individuals come to develop feelings of ownership for those objects. Locke (1690) argued that we own ourselves, we own our labor, and therefore we are likely to feel that we own that which we create, shape, produce and acquire. The more information possessed about the target of ownership, the more intimate becomes the connection between the individual and the object. We tend, for instance, to prefer our own possessions to others (Rudmin & Berry 1987), even others of a similar kind because 'we know them better, realize them more intimately, feel them more deeply' (Horwicz 1878, translated by James 1890).

3. Investing the self in the target. Csikszentmihalyi & Rochberg-Halton (1981) suggested that the investment of an individual's energy, time, effort and attention in objects causes the self to become one with the object. This union between self and object emerges because the object has emerged from the self. In contrast, an employee-ownership arrangement constructed solely around providing the employee with a financial stake in the organization is unlikely to lead to strong feelings of ownership. The investment of the self may come in many forms (for example, the investment of one's time, ideas, skills, decisions, and their physical, psychological, and creative energies), resulting in the target of ownership (or a portion of that target) flowing from the self – creating the conditions whereby the person comes to see him or herself in the target.

Behavioral and organisational scientists have also speculated on the effects stemming from feelings of ownership. There are a myriad of positive and constructive behaviors associated with feelings of ownership for a target (Pierce et al. 2003). These include acts of citizenship, personal sacrifice and the assumption of risk, along with experienced responsibility and stewardship (Box 2).

Box 2. Behaviors associated with feelings of ownership for a target (from Pierce et al. 2003; summary with the original references included).

1. Citizenship. Pierce et al. (2003) proposed that feelings of ownership are positively associated with civic behavior i.e. behavior that contributes to the community's well-being, is voluntary and is intended to be positive in nature, and for which there is no promised or implied *quid pro quo* (Organ 1988). Behavior is, in part, a function of one's self identity, as individuals create and maintain their sense of self by initiating stable patterns of behavior that infuse roles with personal meaning (Burke & Reitzes 1991). When individuals feel ownership of a social entity (e.g., family, group, organization, nation), they are therefore likely to engage in citizenship behaviors towards that entity.

2. Personal sacrifice and the assumption of risk. The willingness to assume personal risk or make personal sacrifice on behalf of a social entity is proposed as another important outcome of feelings of ownership. While such behaviors are part of role requirements in rescue teams, military, police and firefighting organizations, they are important and also occur in other situations where they are not obligatory. For example, people who step forward as "whistle blowers" (e.g., reporting unethical behavior, illegal acts or malfeasance) are taking a personal risk and making a sacrifice for the well-being of their organizations. It has been suggested that such behavior is prompted by a feeling of ownership of the target (e.g., organization).

3. Experienced responsibility and stewardship. Psychological ownership of a particular target may also promote feelings of responsibility that include feelings of being protective, caring and nurturing and a proactive assumption of responsibility for that target. When an individual's sense of self is closely linked to the target, a desire to maintain, protect or enhance that identity will result in an enhanced sense of responsibility (Korman 1970; Dipboye 1977). Closely related to such responsibility are feelings of stewardship, whereby individuals feel responsible as the caretakers of an asset, even though they are not the legal owners. As proposed by Davis et al. (1997), when individuals feel like stewards, they are motivated to act in the best interest of the principals rather than in their own personal interests. It has been suggested that feelings of ownership are likely to create such situations. In other words, when individuals feel ownership, they may feel as though they are the "psychological principals" or stewards and act accordingly.

If this general pattern of how people develop feelings of ownership and the effects of psychological ownership is accurate in the context of natural resource management, then community members who have control over natural resource monitoring, who know a great deal about the monitoring and who invest their own time in it, may feel ownership of the monitoring (Box 1). Moreover, this feeling of ownership may lead to an assumption of responsibility, caring, protection, nurturing, stewardship and a willingness to make personal sacrifices and assume risk on behalf of the natural resource monitoring system (Box 2). Feelings of psychological ownership may also provide incentives for community members to protect their rights to the natural resources and to try to make changes to those elements that they may not be satisfied with (within the limitations provided by the overall policies and power relationships that frame the local situation).

Involving community members in natural resource monitoring may thus have a triple "win" effect. It may simultaneously contribute (1) to empowering local people in natural resource management (through civic behavior), (2) to providing valuable information, and (3) it could effectively lead to sustainable livelihoods and biodiversity conservation (through experienced responsibility and stewardship).

With these field experiences and natural and social science considerations in mind, I therefore decided to examine the potential of locally-based approaches to natural resource monitoring to empower local people in natural resource management, provide high-quality information and impact on livelihood and biodiversity. I used as my point of departure the theory that: '*locally-*

based approaches to natural resource monitoring provide a mechanism for empowering local people, while providing high-quality information, with a higher return on investment in terms of livelihood and biodiversity impact than alternative approaches to monitoring environmental change'. To meaningfully examine this theory, however, I first needed to develop a definition of what is exactly meant by 'locally-based approaches to natural resource monitoring'.

Chapter 2.

Spectrum of approaches to Natural Resource Monitoring

Natural resource monitoring is one of several approaches to evaluating natural resource management. It aims at measuring the status and change in ambient social and ecological conditions (V) and can be undertaken by both scientists and community members (Shirk et al. 2012). Discussion of the relative benefits and disadvantages of professional researcher-executed and locally-based natural resource monitoring tends to be bimodal and focus on these two extremes (Rodríguez 2003; Yoccoz et al. 2003; Gilchrist et al. 2005; I; II; III; IV; XVIII) but, in reality, these simply form the ends of a spectrum of possible monitoring protocols (VI). I decided to examine this gradient more closely, and I therefore led the development of a proposed typology of monitoring systems. The typology was developed on the basis of relative contributions of local stakeholders and professional researchers.

Table 1. Natural resource monitoring systems across a spectrum of possible monitoring approaches based on the relative participation of different actors (adapted from VI). The relative role of local stakeholders in the monitoring systems increases from bottom to top between the five categories of monitoring systems.

Monitoring category		Description
A	Autonomous local monitoring	The whole monitoring process – from design, to data collection, to analysis, and finally to use of data for management decisions – is carried out autonomously by local stakeholders
B	Collaborative monitoring with local data interpretation	Locally-based monitoring involving local stakeholders in data collection, interpretation or analysis, and management decision-making, although external scientists may provide advice and training. The original data collected by local people remain in the area being monitored but copies of the data may be sent to professional researchers for in-depth or larger-scale analysis
C	Collaborative monitoring with external data interpretation	Local stakeholders involved in data collection and monitoring-based management decision-making, but the design of the system and the data analysis and interpretation are undertaken by external scientists
D	Externally driven monitoring with local data collectors	Local stakeholders involved only in data collection stage, with design, analysis and interpretation of monitoring results for decision-making being undertaken by professional researchers, generally far from the site
E	Scientist-executed monitoring	Design and implementation conducted entirely by professional scientists who are funded by external agencies and generally reside elsewhere

Although who tracks resources obviously is an important aspect of natural resource monitoring systems as they can be critical for the outcome of the monitoring, our typology was the first that used local stakeholder and professional researcher involvement for classifying – and thereby for improving the understanding – of natural resource monitoring approaches. We suggested that there are five categories, ranging from efforts where monitoring is undertaken solely by professional researchers to entirely local efforts, with all the work undertaken by local people (Table 1).

The original typology may, however, have suffered from flaws of using 'experts' to think of examples (P.M. Jensen *in litt*.; Sutherland et al. 2004) and it was based on consensus among practitioners. Due to this, I led a process to provide a more objective statistical analysis. In this second phase of the work, a total of ≈3,500 papers were therefore reviewed, presenting published monitoring results since 1987, statistical analysis used to segment published monitoring systems, and a framework of approaches to natural resource monitoring developed (VII). This was the first time that a typology of approaches to natural resource monitoring and management was developed on the basis of robust analysis. This empirically based, statistical analysis corroborated all the categories previously identified (Fig. 2). Within the range from entirely researcher-based efforts to entirely local efforts, monitoring systems were found to fall into five categories defined by the degree of scientist and local participation in system design, data collection, data analysis and implementation of management intervention.

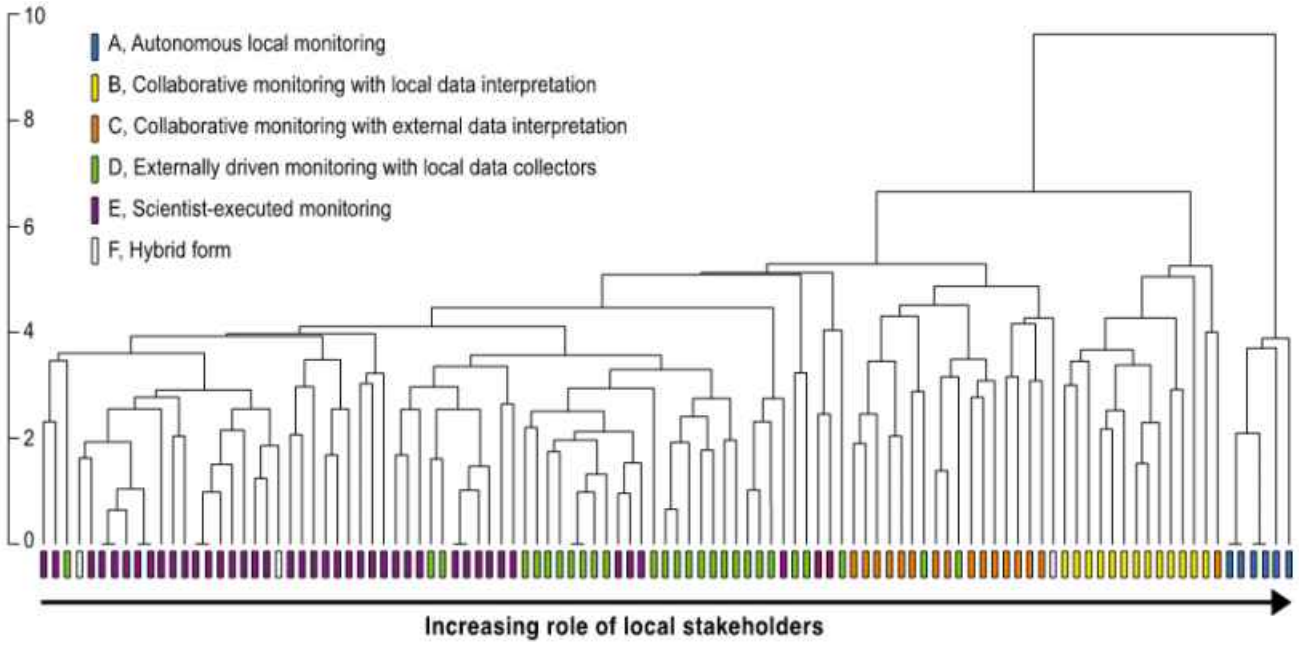

Figure 2. Tree diagram of natural resource monitoring systems, based on a cluster analysis of 17 parameters among 107 monitoring systems (VII). The lowest row of branches represents data (individual published monitoring systems), and the remaining branches represent the clusters to which the data belong. The height of each branch is proportional to the value of the intergroup dissimilarity between its two daughters. The lowest rows of branches are all plotted at zero height. The color of the individual monitoring system represents the category that the system belong to. The relative role of local stakeholders in the monitoring systems increases from left to right between the five categories of monitoring systems.

This statistical approach found that the most distinct monitoring systems were within monitoring system category A (Fig. 2) and have two unique characteristics: (1) local stakeholders took the initiative to set them up; and (2) they are fully locally financed: scientists are not involved. The second most distinct group is monitoring system category B. In these systems, scientists took the original initiative, but local stakeholders collect, process and interpret the data. The third most distinct group is monitoring system category C. Scientists, who also analyze the data, designed these systems, but the local stakeholders collect the data, take decisions on the basis of the findings, and carry out the management interventions emanating from the monitoring system.

The least distinct clusters are monitoring system categories D and E (Fig. 2). In category D, local stakeholders are involved in data collection but other activities are carried out by professional scientists. In monitoring systems of category E, all aspects of the monitoring are undertaken by professional scientists, without the involvement of local stakeholders. These five categories of monitoring system are not mutually exclusive and hybrid models exist (Fig. 2). Examples of monitoring systems belonging to the five categories are described in VI and VII.

The monitoring systems of the three participatory categories (category A, B and C) are mainly 'monitoring for participants' to improve their livelihoods (Staddon et al. 2012; VII). Conversely, scientist-led systems (category D and E) are 'monitoring for others' to protect biodiversity. I consider monitoring systems of the three most participatory categories to be 'locally-based approaches' to monitoring.

The continuum of monitoring approaches generally mirrors the devolution of management responsibility in different approaches to natural resource management (VI). The most locally-based monitoring systems (category A) are typically part of "traditional" or "customary" systems of natural resource management (Berkes 2012; Staddon et al. 2014), and management responsibility may always have been at this level. The second most locally-based system (category B) is equivalent to community-based natural resource management, in which management decisions and other rights have been devolved to the community. Monitoring systems within category C and partly in category D mirror some of the more collaborative systems in natural resource management, for example, systems such as joint forest management, in which management rights and responsibilities have not been devolved but there is a sharing of management costs and benefits (Blomley & Ramadhani 2006). Finally, the least locally-based of the monitoring systems (category E and partly category D) parallel those natural resource management approaches that do not involve local people and in which the majority of decisions are made by remote government agencies or civil society organizations.

The theoretical 'routes' to feelings of ownership of a natural resource monitoring programme (control over the programme, intimate knowledge of the programme and investment of self in the programme; Pierce et al. 2003) all increase in importance with the increasing role of local stakeholders across this spectrum of natural resource monitoring approaches (Table 1). Strong feelings of ownership of a monitoring programme are unlikely to manifest themselves if the community members are only involved in the data collection stage as volunteers or paid staff

without any control over the monitoring programme (category D). Likewise, this theory predicts stronger feelings of ownership when the data analysis and interpretation are led by community members (category A and B), than when these activities are primarily the domain of scientists (category C).

Chapter 3.

Empowering local people through Natural Resource Monitoring

After having defined and discussed what exactly is meant by locally-based approaches to natural resource monitoring, I divided my theory into three separate hypotheses. I first address the hypothesis that '*locally-based approaches to natural resource monitoring provide a mechanism for empowering local people'*.

Maton (2008) defined empowerment as "a participatory, developmental process through which marginalized or oppressed individuals and groups gain greater control over their lives and environment, acquire valued resources and basic rights, and achieve important life goals and reduced societal marginalization". For current purposes I define empowerment as: "a participatory, developmental process through which marginalized individuals and groups gain greater influence over their livelihoods and acquire improved control over valued natural resources".

Empowerment can occur in different dimensions (Speer & Hughey 1995; Maton 2008; Constantino et al. 2012). These dimensions include: (1) psychological (e.g., development of pride and self-esteem in natural resource management); (2) political (e.g., participation in natural resource decision-making, development of leadership, increased local governance over natural resources); (3) social (e.g., education, improvement of local organizations involved with managing natural resources); and (4) economic (e.g., financial resources, control of subsistence resources). During my initial studies (IV; XIX), I was mainly interested in (1) and (4), but over the years, my focus changed to (2), (3) and (4) (IX; X).

To address my hypothesis, I expected local stakeholders' involvement in monitoring would increase their control over the land and resources. Under the research program I led, social scientist Dr Mikkel Funder et al. (IX) examined how community members *responded* to a locally-based natural resource monitoring system. This provided important insights into the empowerment of a real-world case of a locally-based monitoring system. To my knowledge this was the first quantitative study of community member responses to a natural resource monitoring system (see also Constantino et al. 2012).

We studied a natural resource monitoring system in Tanzania, four years after external assistance to the monitoring system had ceased. The monitoring system was aimed at providing information on the status and trends of forest use and forest and wildlife resources, for use by communities in daily forest management in Participatory Forest Management (PFM) areas (Topp-Jørgensen et al. 2005;

VIII). It was established in Iringa and Kilolo Districts, during 2001-2002, and shortly after no further assistance was provided to the monitors.

Four years on, in 2008-2009, it was assessed whether the monitoring system was continuing in the villages where it had been established (IX). Household questionnaires, in-depth qualitative interviews and focus group interviews were used in four villages to examine how community members were responding to the monitoring system. A total of 160 households were asked about their livelihoods, forest use and overall perceptions of and engagement with the monitoring system. The selection of respondents was based on stratified sampling using 'well-being rankings' (Grandin 1988; IIED 1992). Qualitative interviews were conducted with 39 households, centered on tracing people's actions in relation to the local community monitoring system since its initiation, and exploring their rationales and perceptions *vis-à-vis* the monitoring system. This was complemented by interviews with members from each of the different well-being categories ('Poorest', 'Middle', and 'Wealthy' households), members from different forest user groups, and members of the Village Natural Resource Committees that were operating the monitoring system in the four villages (IX). The Village Natural Resource Committees are the designated forest managers of the PFM areas (VIII).

Even though external financial and technical support had terminated four years earlier, the system was continuing to operate in most of the original 23 target villages (IX). In most villages, Village Natural Resource Committee meetings where monitoring results were discussed were being held on a monthly or bi-monthly basis. Moreover, the system had retained the broad support of community members. In the four villages covered by the household survey, 86% of all respondents said they felt the monitoring system benefitted their household (n = 160 households).

This broad ownership to and local support for the monitoring system and its continuation entirely without external assistance prompted search for an explanation. When asked directly to name the benefits of the monitoring system, all of the 138 respondents that were favorable to the system mentioned protection against encroachment on forest resources as the main benefit from the system. This was also shown by the qualitative interviews with individuals and focus groups in the four villages. During these interviews, community members placed great emphasis on how the monitoring system was a way of supporting individual and collective access to and control over resources, thereby ensuring long-term access to natural ecosystem products and services. Indeed, during ranking exercises, focus groups and most individuals consistently ranked improved community control over forest resources as the most significant benefit of the monitoring system. The monitoring system is thus perceived and used by community members as a means of asserting and reenforcing rights over forest resources.

These findings suggest that the monitoring system in Tanzania has provided an organisational and political arena for community empowerment and that the communities are able to influence and adapt the monitoring system according to their needs. When the monitoring system was established, it was not envisaged that it would be used as a platform for pursuing and consolidating community forest rights.

The community involvement in producing knowledge and in the associated decision-making and actions generated power and influence for the communities. This was probably because information in itself provides power to the information-holder (Blaikie et al. 1997) and because the monitoring process provided a concrete forum for negotiation, action and resistance (IV). The natural resource information was generated within a monitoring system established to follow normal scientific requirements for objectivity. It was therefore particularly difficult for government decision-makers to ignore the findings from the monitoring. The opportunities that the monitoring system provided for community members did not, however, always play out equitably within communities and further work is needed to explore how 'elite capture' of the monitoring process can be avoided (Labonne & Chase 2009; Lund & Saito-Jensen 2013; IX).

While locally-based natural resource monitoring undertaken in isolation from the governance of natural resources is unlikely to significantly empower community members (VIII), the findings from Tanzania provide preliminary evidence that when community-led monitoring activities are an integrated part of the natural resource governance system, the locally-based monitoring can be a very important mechanism for political, social and economic empowerment of the community members (IX). In particular, in terms of *political empowerment*, the application and generation of local knowledge in the Tanzanian monitoring system led to greater local influence on and involvement in natural resource management decisions. In terms of *social empowerment*, the monitoring led to improved local organizations for management of resources; and in terms of *economic empowerment*, the monitoring led to increased local control of subsistence resources.

Other examples of evidence of increased local empowerment from community member participation in locally-based natural resource monitoring come from the Philippines, where indigenous resource-use regulation systems were re-established with government recognition in several protected areas (XIX). I likewise observed in Greenland that a primary reason for the interest in locally-based natural resource monitoring among community members stems from the fact that enrolling in the monitoring provides an opportunity for the participants' insights and knowledge on natural resources to be used and their voices to be heard (X).

The 'process' aspect of locally-based natural resource monitoring systems is, however, very important to the community members' sense of empowerment (XV). The most profound empowerment is likely to be achieved when community members themselves are the 'gate keepers', detecting and deciding which data are complete and which are false, or out of context and therefore need to be discarded. Community members' ownership of the data and information and their control over the knowledge, the validation process and the application of the knowledge are critical (Stephenson & Moller 2009; Huntington 2011). The importance of community members themselves having control over the process concurs with current theorizing on psychological ownership (Pierce et al. 2003; Pierce & Jussila 2011) in that feelings of ownership increase when people have control over the monitoring programme e.g. over *how* monitoring data are collected and *what* they are used for.

Locally-based approaches to natural resource monitoring seem to have potential to empower community members, but if the methods are unable to deliver quality-information, they may at best only serve to raise awareness and at worst lead to actions directed at wrong targets. It is therefore very important to know if locally-based approaches to natural resource monitoring can deliver quality information.

Chapter 4.

Quality of information from locally-based approaches

Scientists trained in biological sampling design and field data collection techniques are generally expected to collect data on natural resource trends more accurately than do local people, who may lack a formal education (Penrose & Call 1995). Local people are also expected to be less objective than external scientists when they record the status of natural resources, because of vested interests in their use of those resources (Root & Alpert 1994). Given such concerns, the ability of locally-based approaches to natural resource monitoring to accurately detect changes in natural resource populations or patterns of resource use has been widely questioned (Holt et al. 2013; II; XVIII). If monitoring by local communities is inaccurate or biased, it may not be reliable for assessing trends in the natural world, and management interventions may be directed inappropriately (Burton 2012; Nielsen & Lund 2012).

The second hypothesis I address is therefore that *'locally-based approaches to natural resource monitoring provide high-quality information'*. In order to test the hypothesis, I made the assumption that measurements by community members would compare well with closely similar measurements by scientists. To test this belief five evaluations of the quality of information from locally-based natural resource monitoring were completed (Table 2). The results are summarized in the following five sections.

Table 2. Study areas, attributes monitored, and methods used in five studies of the quality of information from locally-based natural resource monitoring.

Study number	Study and country	Habitat	Attribute(s) being monitored	Methods being compared	
				Community member survey method	Trained scientist survey method
1	X; Greenland	Arctic coastal and marine	Abundance of sea-ice, fish, mammals, birds, and resource uses	Perceptions of experienced fishers and hunters; focus group discussions	Various (retrospective, opportunistic)
2	XI; XII; Tanzania, Madagascar, India	Miombo woodland, montane evergreen forest, dry deciduous forest, temperate mountain forest	Forest degradation, woody biomass, cut trees	Vegetation plots, patrol records of cut trees	Vegetation plots, line transect surveys of cut trees
3	XIII; China, Laos, Vietnam, Indonesia	Lowland dipterocarp forest, mountain rainforest, evergreen monsoon forest	Woody biomass	Vegetation plots	Vegetation plots
4	XIV; Nicaragua, Tanzania, Madagascar, Philippines	Lowland dipterocarp forest, mountain rainforest, miombo woodland, montane evergreen forest, dry deciduous forest	Abundance of mammals, birds, and resource uses	Patrol records	Line-transect surveys
5	XV; Nicaragua	Lowland dipterocarp forest	Abundance of mammals, birds, and plants	Perceptions of experienced forest users; focus group discussions	Line-transect surveys

4.1 Studies of the quality of information

Study 1: Comparison of community members' perceptions with trained scientists' reports in Greenland

Looking towards the North, in Greenland, I compared experienced community members' perceptions with scientists' reports of trends in the abundance of 24 attributes that were summarized by 33 community members 2009-2011 (X). To my knowledge this is the first time that the findings from a community-based programme dedicated to monitor a spectrum of living resources in the Arctic was compared with trained scientists' reports (see also Gilchrist et al. 2005; Laidler 2006; Krupnik et al. 2010; Merkel 2010; Weatherhead et al. 2010; Eira et al. 2013).

The community members and the professional scientists produced similar results for 12 attributes: spotted wolffish *Anarhichas minor,* harp seal *Phoca groenlandica*, humpback whale *Megaptera novaeangliae*, minke whale *Balaenoptera acutorostrata*, caribou *Rangifer tarandus*, snow goose *Anser caerulescens*, Greenland white-fronted goose *A. albifrons flavirostris*, Canada goose *Branta canadensis*, common eider *Somateria mollissima*, breeding Brünnich's guillemot *Uria lomvia*, winter sea-ice, and shipping. Only for two populations, nearshore Greenland halibut *Reinhardtius hippoglossoides* and breeding Arctic tern *Sterna paradisaea*, was there disagreement between local and scientists' reports of trends in abundance. For ten attributes, it was not possible to locate any scientist-produced data to allow for a comparison with the community members' findings (Table 3).

In this study, some areas however remained subjective. First, the local reports may not only have been based on local observations and local knowledge but may also have been influenced by publicity surrounding scientific findings that have become accepted knowledge in a local community (Huntington et al. 2004). Second, the approach was retrospective and opportunistic, and insufficient match between the area, time and geographical and temporal scale of the local and scientists' reports may have affected the comparisons. Nevertheless, my results provide preliminary support for the idea that community-based monitoring in the Arctic can yield locally-relevant results that can be as reliable as those derived from professional scientist-executed monitoring.

Study 2: Comparison of community members' and trained scientists' measurement of forest condition

Looking towards the South, in India, Tanzania and Madagascar, I took initiative to a study, co-led by forester Dr Margaret Skutsch, to investigate how well community members can measure forest degradation by comparing statistically the results of community-based and professionally-executed monitoring of forest degradation (biomass and utilization) (XI).

Study sites were chosen opportunistically (biomass measurements) and on the basis of existing locally-based forest utilization monitoring systems (forest utilization measurements). Representatives of the local communities in the study sites helped us select community participants based on their interest in, and experience of, forest resources. Community members involved in

measuring forest condition had only attended primary school but received training from a civil society organization, while the professional experts had academic degrees in the natural sciences.

Table 3. Comparison of community members' perceptions and trained scientists' assessments of trends in abundance of sea-ice, two human activities and 21 populations of fish, mammals and birds in North West Greenland 2009-2011 (X).

Attribute		Percep-tions*	Scientists' assessments	Source of scientists' assessments*	Correspon-dence
Fish	Atlantic cod, D	‡	Few data	Siegstad 2011	N.a.
	Wolffish *spp.,* D	↑	↑/⇔	Siegstad 2012	(✔)
	Greenland halibut	↑	↓/⇔	Siegstad 2011; 2012	⃠
Marine mammals	Ringed seal	↓	Few data	Boertmann 2007; Rosing-Asvid 2010	N.a.
	Harp seal, D	↑	↑	Department of Fisheries and Oceans 2010; Rosing-Asvid 2010	✔
	Narwhale	‡	Few data	North Atlantic Marine Mammal Commission 2012	N.a.
	Humpback whale	↑	↑	Heide-Jørgensen et al. 2011	(✔)
	Minke whale, D	↑	↑	Heide-Jørgensen et al. 2010	(✔)
	Minke whale, U	⇔	Few data	No information	N.a.
Land mammals	Arctic fox, D	↑	Few data	Boertmann 2007	N.a.
	Caribou, N	⇔	⇔	Cuyler et al. 2005; Cuyler & Nymand 2011	✔
	Musk ox, L	‡	Few data	No information	N.a.
Birds	Snow goose, D	↑	↑	Boertman 2007	✔
	Greenland white-fronted goose, U	↓	↓	Boertmann 2007; Boyd & Fox 2008	✔
	Canada goose	↑	↑	Bennike 1990; Fox et al. 1996; Boertman 2007	✔
	Common eider	↑	↑	Chaulk et al. 2005; Merkel 2010	(✔)
	White-tailed eagle, D	↑	Few data	No information	N.a.
	Large gulls*, D	↑	Few data	Boertmann 2007	N.a.
	Arctic tern, D	↑	⇔	Boertmann 2007; Egevang & Frederiksen 2011	⃠
	Brünnich's guillemot, breeding	↓	↓	Burnham et al. 2005; Labansen & Merkel 2012	✔
	Little auk, D	↑	Few data	Egevang & Boertmann 2001; Boertmann 2007	N.a.
Other	Winter sea-ice*, U	↓	↓	Danish Meteorological Institute	✔
	Offshore ships, U	↑	↑	Arctic Marine Shipping Assessment 2009	(✔)
	Trawling, D	↑	Few data	No information	N.a.

Legend: ↑, increased abundance; ↓, declining abundance; ⇔, no major change in abundance; ‡, increased abundance reported in some areas, decline in other areas; Few data, there is little or no abundance data available; ✔, correspondence between community members' and scientists' assessments; (✔), probable correspondence between community members' and scientists' assessments but the time, area and/or temporal/spatial scale of the assessments do not match; ⃠, no correspondence. D, Disko Bugt; L, Naternaq/Lersletten and Svartenhuk; N, Nassuttooq/Nordre Strømfjord; N.a., not applicable; U, Uummannaq Fjord. *For literature cited, latin names and further details, see X.

For forest biomass, we compared above-ground biomass from three sites in India and one site in East Tanzania. For forest utilization, we compared five sites in the Eastern Arc Mountains of Tanzania and 10 sites in Madagascar. From these 19 study sites, I chose a set of eight "core sites" for graphical presentation of the results (Fig. 3). The core sites were selected to ensure they were representative of the full range of forest biomass and forest resource-use intensities.

For the measurement of forest biomass, community members first identified forest strata (defined as areas of homogeneous forest; XI) with the assistance of an intermediate organization, after which community members and trained scientists independently carried out forest inventories on permanent plots based on the methodology recommended by the Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance (Penman et al. 2003). The community members used advanced mobile device technology (hand-held computers) for encoding tree measurements in the field. For the measurement of forest utilization, community members recorded the number of cut trees during regular patrols and we compared their results with those from scientists. I adjusted the counts of cut trees for differences in effort by dividing the counts by the number of hours taken for the surveys in the relevant 3-month period (quarter) at the given site.

We first tested for differences between community members' and trained scientists' forest biomass data. Over a range of forest biomass intensities from 450 to less than 50 $Mgha^{-1}$ woody biomass — that is, *dense* temperate mountain forest (core site 1), temperate mountain forest (core site 2), and degraded forest (core site 3) in India, and miombo woodland in Tanzania (core site 4) — we found no significant differences in the estimates of mean above-ground biomass made by community members and by trained scientists (n = 125 permanent plots; Fig. 3a). The local biomass estimates are reliable compared to professional estimates over a range of forest sites from high carbon to low-carbon forest types.

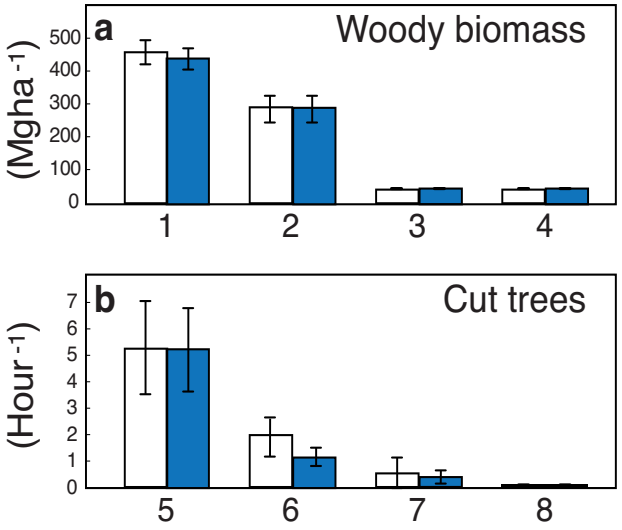

Figure 3. Comparison of forest condition data compiled by community members and trained scientists (XI). Measurements of woody biomass (a, core sites 1-4) and cut trees (b, core sites 5-8) (± S.E.) by community members (white) and trained scientists (blue) over a range of forest biomass and resource-use intensities in *dense* temperate mountain forest (core site 1), temperate mountain forest (core site 2) and degraded forest (core site 3) in India, miombo woodland in Tanzania (core sites 4-6), and dry deciduous forest in Madagascar (core sites 7-8).

We then compared the number of cut trees per hour as recorded by community members and by trained scientists, which provides an estimate of the rate of forest degradation and impact on carbon stock. Over a range of forest resource-use intensities – from more than five to less than 0.1 cut trees per hour of census in heavily used miombo woodland in Tanzania (core site 5–6), montane evergreen forest in Tanzania, and dry deciduous forest in Madagascar (core site 7–8) – we found no significant difference in utilization estimates by community members and by scientists (*P*-values > 0.05; $n = 99$ three-month periods; core sites shown in Fig. 3b).

Moreover, community measurements cost significantly less than scientists' measurements because of savings in transport and salaries (XII). The average costs per hectare of community monitoring of biomass in tropical forests are highly variable but decrease over time as the communities become more proficient in tree measuring from year to year, and also decrease as forest size increase (Brofeldt et al. 2014; XII).

These findings demonstrate that local communities can collect forest condition and biomass data of comparable quality to trained scientists in relatively simple-structured forests. However, many forests are more difficult to monitor. It was not known if local communities can monitor above-ground biomass in the complex old-growth tropical forests of South America, Africa or South East Asia, where the large number of species and difficult access make surveys much more challenging. Moreover, the local forest biomass monitoring protocols relied on the use of hand-held computers (Peters-Guarin & McCall 2011), which may represent a constraint to community involvement and the broad-scale implementation of local community monitoring of forest condition because capacity is limited in some communities (Howell 2012). Employing low-tech field approaches, such as recording of data using pen and paper, measuring using ropes marked at relevant points, and utilizing other feasible protocols for local communities, may greatly enhance the application of the local approach to monitoring forest condition.

Study 3: Comparison of community members' and trained scientists' measurement of forest biomass

I therefore decided to extend the comparison of local people's and scientists' forest biomass data to more complex forests: tropical lowland dipterocarp forest in Indonesia, evergreen monsoon forest in Laos and Vietnam, and mountain rainforest in China. We abandoned hand-held computers and instead used only a Geographical Positioning System (GPS) device, measuring tape, rope for measuring plots, paint, paper and pen (XIII). This was the first time where low tech field measurement approaches by community members were compared with trained scientists measurements of forest biomass.

For this study, we chose study sites opportunistically in the four South East Asian countries. Representatives of the local communities in these sites helped us select community participants using the same criteria as in the previous study i.e. the community members' interest in and experience of forest resources.

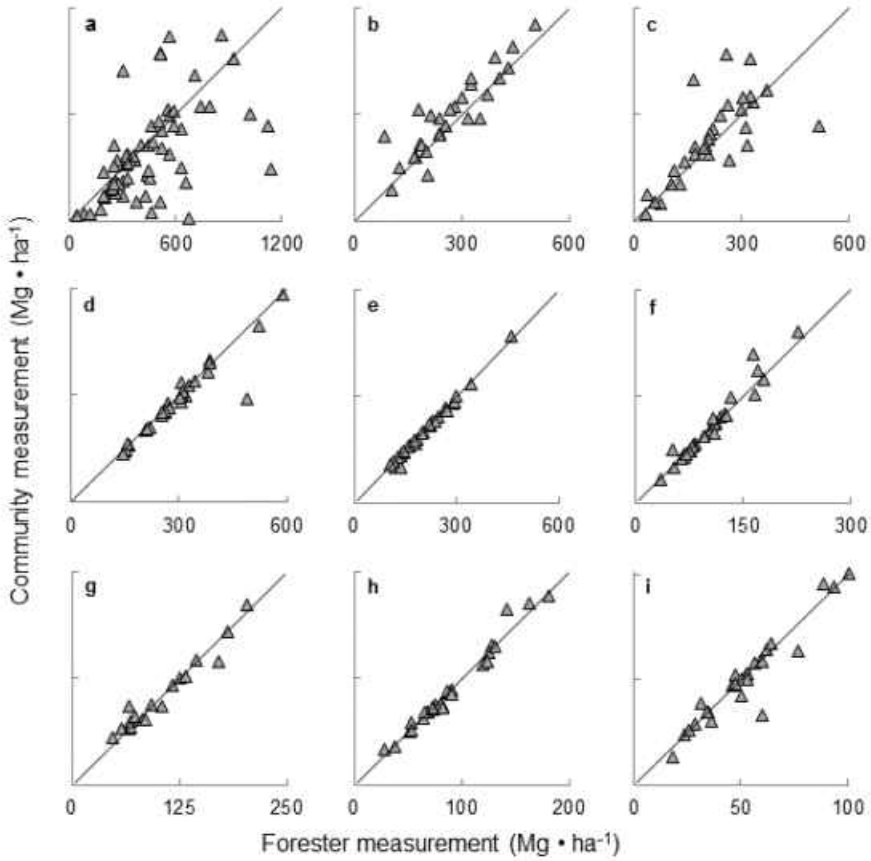

Figure 4. Relationship between the woody biomass recorded by community members and trained scientists plot-based woody biomass measurements in lowland dipterocarp forest in Indonesia (a), mountain rainforest in China (b–c), evergreen monsoon forest in Laos (d–e), and Vietnam (f-i) (with same units on *y*-axes as on *x*-axes and $y = x$ lines; n = 289 permanent plots; XIII). Each point in the graphs represents one census of above-ground woody biomass in a permanent vegetation plot by community members (*y*-axes) and trained scientists (*x*-axes).

I led a process where we compared above-ground biomass from nine sites: one site in Indonesia, two sites each in China and Laos, and four sites in Vietnam. I found that the biomass estimated by community members after the first year of measurements differed overall only slightly from the estimates of trained scientists, Figs. 4-5. However, the data sets of community members and scientists did not completely match. Two plots were excluded due to violations of 3x standard deviation: one plot in Indonesia and one in Vietnam. Both were due to outlying values among community measurements where trees were assessed as 2-5 m larger in circumference by community monitors than by the scientists. These errors were easily identifiable and occurred in only two out of 289 plots, but they highlight the need for proper validation of all field data.

These findings corroborate the evidence that local stakeholders with limited education can monitor forest biomass. The findings also show there is no real need for hand-held computers to capture data, as long as data entry can be completed by community members with computer skills or by a civil society organization using a spreadsheet program in a computer upon return from the field surveys. This is necessary in order to convert tree girth data to biomass (and hence to carbon).

Community members' measurements of forest condition compared well with closely similar measurements by scientists, not only in simple-structured forests where hand-held computers were used (XI) but also in difficult to access, complex forests where low-tech field approaches were used (XIII).

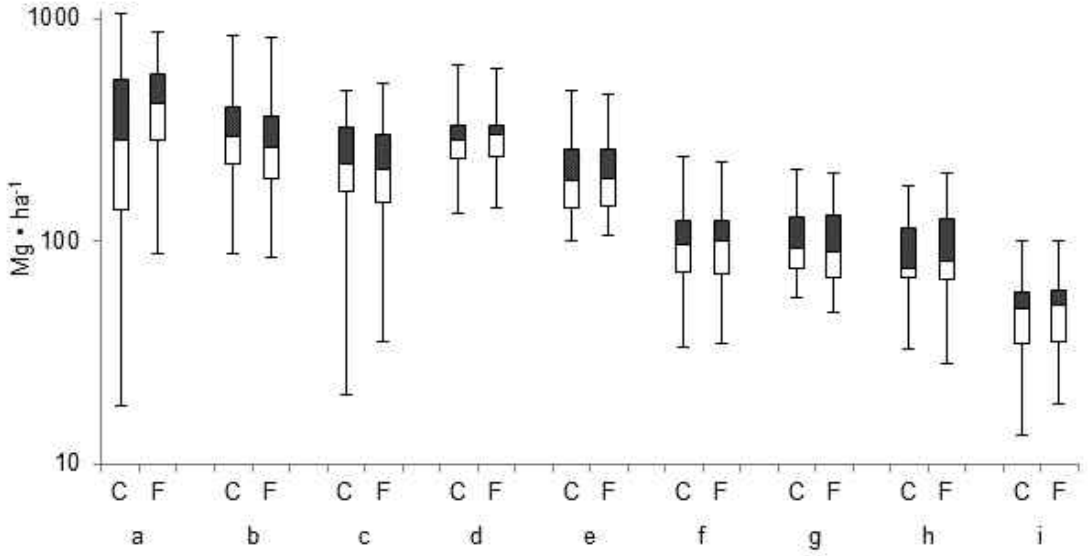

Figure 5. Comparison of woody biomass data in diverse South East Asian forests compiled by community members and trained scientists. Measurements of above-ground woody biomass were made by community members (C) and trained forest scientists (F) over a range of lowland dipterocarp forest in Indonesia (a), mountain rainforest in China (b–c), evergreen monsoon forest in Laos (d–e), and Vietnam (f–i) (n = 289 permanent plots; $\log_{10}$ scale; XIII). The different points in each column show the smallest observation, lower quartile, median, upper quartile, and largest observation.

Study 4: Comparison of community members' and trained scientists' sampling of forest biodiversity

Forest biomass is only one of many resources in the tropical forests. It is of broader interest if community members can also monitor forest biodiversity (Luzar et al. 2011). Biodiversity is however a much more complex measure and may thus be far more challenging to monitor. To examine the quality of locally-based approaches to biodiversity monitoring, I led a process to compare data on status and trends in natural resources collected independently by local community members and trained scientists for 63 taxa and 5 types of resource use in 34 tropical forest sites across 4 countries over 2.5 years (XIV).

Previous field investigations in which the accuracy of biodiversity information generated by local communities in developing regions was assessed have been qualitative studies, individual case studies, or limited by small sample sizes (XIV). All of the individual case studies and those with small sample sizes have been restricted to small geographical areas. Most have been focused on a comparison of static findings – for example, population density at a single point in time. Few have

involved trends over time, which is critical when resource monitoring is intended to inform natural resource management and sustainable use (Jones et al. 2008). From my review, in only eight studies was field data collected by locals and that collected by external groups from the same areas and at the same time of year compared (XIV). Taken together, these previous studies provide cautious support for the idea that monitoring of natural resources by local people can provide accurate data.

This study was undertaken in Madagascar, Nicaragua, the Philippines and Tanzania, where study sites were located opportunistically on the basis of existing locally-based forest monitoring systems, except in Nicaragua where we established a local monitoring system for the purpose of this experiment.

The community participants included some of the most experienced collectors of forest products in each study site. Most of them had only attended primary school. The scientists all had academic degrees in natural science and ≥ ten years of prior field experience in tropical forest biodiversity surveying.

Prior to fieldwork, we asked the community participants to select the natural resources and resource-use events that they would like to monitor. The community members decided on 68 targets to be monitored, which were divided into three classes: birds (39 taxa), mammals (24 taxa) and resource uses (e.g., 'cut bamboo'; 5 types of resource use). Most of these resources were of value to local people.

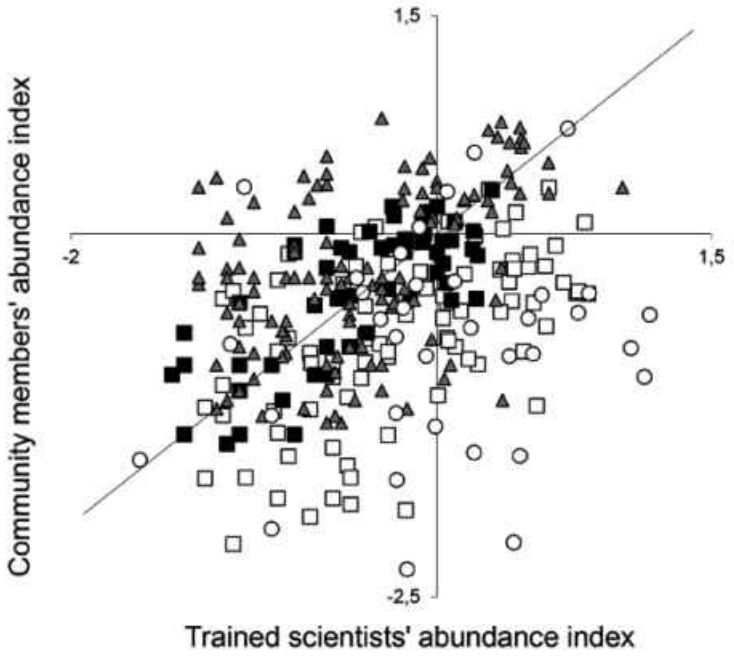

Figure 6. Relationship between the community members' and trained scientists' indices of abundance of 68 forest resources and forest uses recorded between 2007 and 2009 at 34 sites in Madagascar (the white squares), Nicaragua (the black squares), the Philippines (the triangles) and Tanzania (the circles) (n = 300 pairs of observations; $\log_{10}$ scales; XIV). Each point on the graph represents a time series of records based on the mean counts per hour of quarterly registrations of one resource or resource-use event at one site by community members (y-axis) and trained scientists (x-axis). The diagonal line represents $y = x$.

Community members recorded sightings and signs of birds, mammals and resource uses during regular foot patrols in the forest. Scientists carried out surveys of birds, mammals and resource use along fixed routes within the same forest study sites, using a variable distance line transect method. We did not standardize the shape, length or location of community member survey routes between the countries; this was because all local systems, except in Nicaragua, were based on community monitoring systems existing prior to this study.

A total of 24,881 hours of monitoring by community members (19,183 hours) and trained scientists (5,698 hours) generated 5,804 paired records between community members and scientists measuring the same natural resource or resource-use activity at the same site in the same three-month period. The relationship between community members' and scientists' findings of the abundance of biodiversity was less clear (Fig. 6) than in the study of woody biomass (Fig. 4). However, I found that, despite considerable differences between countries, cultures and types of natural resource monitored, community members and trained scientists produced closely similar results on status of and trends in species and natural resources (Figs. 7-8; XIV).

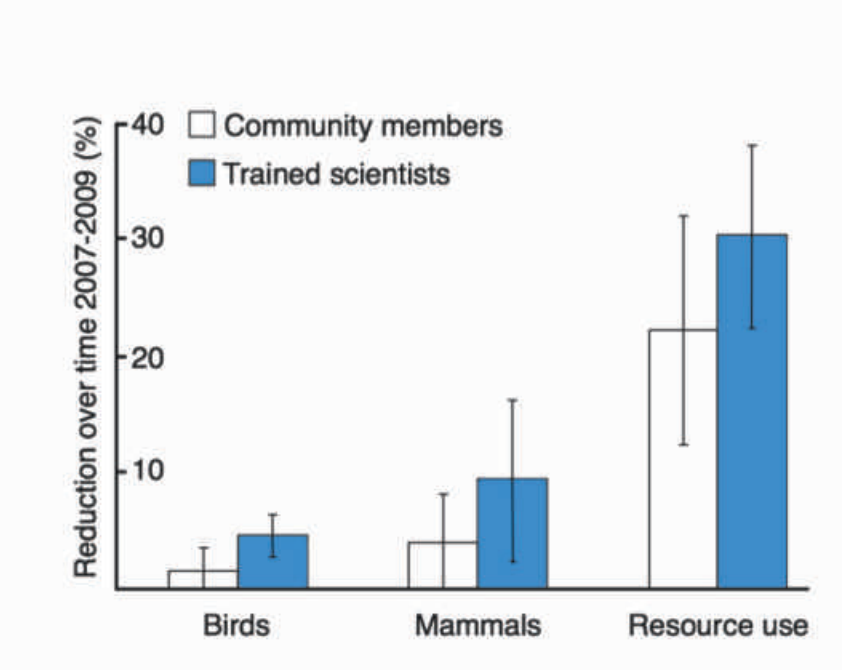

Figure 7. Relative abundance (as the reduction percentage) of 68 forest resources and forest uses recorded by community members (white) and trained scientists (blue) between 2007 and 2009 at 34 sites in Madagascar, Nicaragua, the Philippines and Tanzania. All of the trends are negative, and the *y*-axis is therefore inverted (n = 300 pairs of observations; each paired observation represents a time series of parallel records of sequential quarterly registrations of one resource or resource-use event at one site by community members and trained scientists; XIV). The error bars represent the standard error (S.E.).

These findings suggest that, in tropical forest habitats, community members with little or no formal scientific education, who have decided which natural resources should be monitored, can generate very similar results on the abundance estimates, relative trends and temporal variation of natural resources and resource uses when compared to trained scientists. I found the greatest match in results between the two groups of observers when they surveyed the same route (Nicaragua, Philippines) with short time intervals between their surveys (Nicaragua). I found the lowest match

in results when community members varied their survey routes among patrols (Tanzania). I also found matches in relative trends over time, but no match in static abundance estimates, when scientists surveyed forest routes and community members surveyed forest boundary-routes and there were long time gaps between scientist and community member surveys (Madagascar). When there were only small differences in route, area and time of the surveys by community members and trained scientists, they produced closely similar estimates.

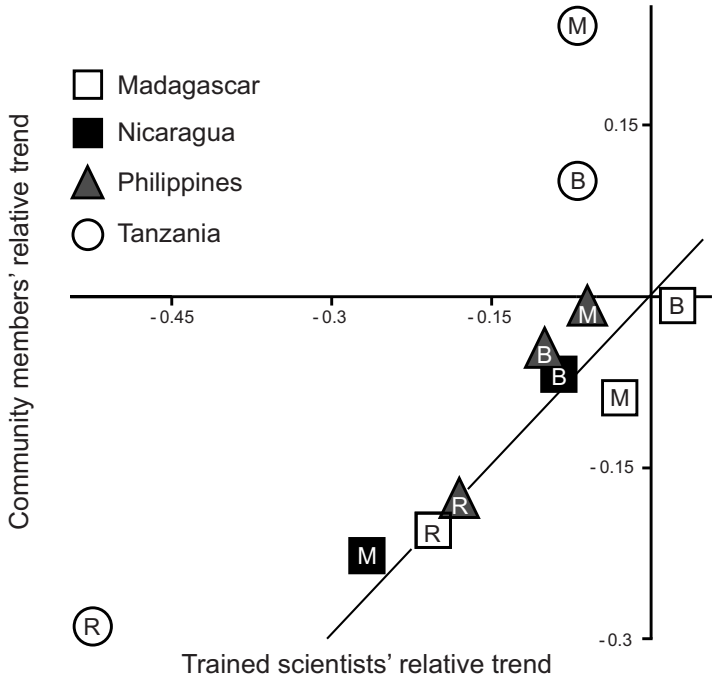

Figure 8. Relative abundance of 68 forest resources and forest uses recorded by community members and trained scientists between 2007 and 2009 at 34 sites in Madagascar, Nicaragua, the Philippines and Tanzania (n = 300 pairs of observations; XIV). The diagonal line represents $y = x$. Abbreviations: B, birds; M, mammals; R, resource use.

Study 5: Comparison of community members' perceptions with trained scientists' sampling of biodiversity

The previous study relied on community members writing down their observations. In many cultural and socio-economic settings across the world, knowledge transmission is mainly oral (Ohmagari & Berkes 1997). In these areas, community members prefer to avoid writing down their observations and instead report their perceptions verbally during discussions with other members of the same community at small meetings. Employing systematic focus group discussions with knowledgeable community members without each individual necessarily recording her/his observations in writing may greatly enhance the application of the local approach to monitoring natural resources. To evaluate the quality of information from focus groups, I led a study where we compared local people's biodiversity abundance data collected through community focus groups with scientists' line transects of the same species in the same areas and three-month-period.

I know of only one previous comparison of focus group results with direct counts of natural resources (Mueller et al. 2010). This compared assessments of species richness, diversity and height of grasses and trees by community members from a village in Niger, with direct counts made by scientists. The study found a good match on height and density for grasses and trees and tree species richness, but it found poor correlation on herb species richness and Simpson's *D* value for both trees and grasses. The study does, however, suffer from different temporal scale and different times for community members' focus group discussions and direct counts, thus preventing conclusions on the reliability of the focus group.

I compared assessments of abundance of natural resources made by focus groups comprising community members of Miskito and Mayangna communities in Bosawás Biosphere Reserve in Nicaragua with line transect surveys conducted by trained scientists and community members (XV). We established focus groups of community members in two villages and independent line transect routes at nine study sites in the adjacent forests. The line transect routes were surveyed for both animals and plants by community members and trained scientists.

In this study, the community members in focus groups had attended the first years of primary school and were only semi-literate. In contrast, community members involved in line transect had completed primary school and were literate. The scientists had academic degrees in natural science and ≥ ten years of prior field experience in tropical forest biodiversity surveying.

Prior to the fieldwork and the focus group discussions, the scientists and community members had agreed on 10 resources important to the communities for food or other uses that should be assessed. Community leaders helped establish focus groups, based on villagers' interest in and experience of forest resources. Group members included forest product harvesters, hunters, loggers and local protected area rangers, of both genders. In each village, we established a volunteer focus group of 10–20 people who observed forest resources at the study sites between discussions. Over 2 years and 6 months, these people took part in a 2–3 hour meeting every three months. The facilitator questioned the participants about the abundance of each resource at the study sites in that particular three-month period. Four natural resource abundance categories were used, ranging from 'many' (category 1) to 'very few' (category 4).

One researcher recorded sightings and signs of wildlife and plants along a predetermined 2 km transect in the forest of each study site, once every three months over 2 hours. Community members carried out comparable line transect surveys along the same routes, but on different days. I compared the abundance reports assigned by the focus groups to each species at each study site for each three-month period with the actual number of individuals recorded during trained scientists' and community members' transect walks in the same study sites and three-month periods.

The test was based on 430 tripled records from focus groups, trained scientists and community member transects of the same 10 resources (3 plants, 3 birds and 4 mammal taxa) in the same areas (9 sites) and at the same time (same three-month period). I first tested differences in the recorded relative abundance of resources between trained scientists and community member transects. No

significant differences were recorded between the estimates of abundance of mammals ($P = 0.28$), birds ($P = 0.58$) or plants ($P = 0.08$) made by trained scientists and community members on surveys of the same transect routes.

I then compared the focus groups and the averaged transect results. I found that focus group discussions were unable to differentiate between what the community members and trained scientists considered 'very few', 'few' and 'some individuals' but that resources reported to be plentiful were reported significantly differently from all other categories for all three types of resources (Fig. 9).

The apparent lack of ability of focus group reports to differentiate between the three categories of least abundance was caused by high standard deviation within focus-group category 4 ('very few') and by fairly even densities of focus-group category 3 ('few individuals') and 2 ('some individuals'). Reducing the number of categories of relative abundance from four to three, by merging the categories 'few individuals' and 'some individuals', led to a clearer separation of the relative densities in the categories for birds and plants, although not for mammals. Likewise, I found that Spearman correlation coefficients for relative densities and focus-group categories were 0.43 ($P < 0.001$), 0.06 ($P = 0.32$) and 0.30 ($P = 0.04$) for birds, mammals and plants, respectively, suggesting a step-wise reduction in densities by focus-group category for birds and plants, but not for mammals.

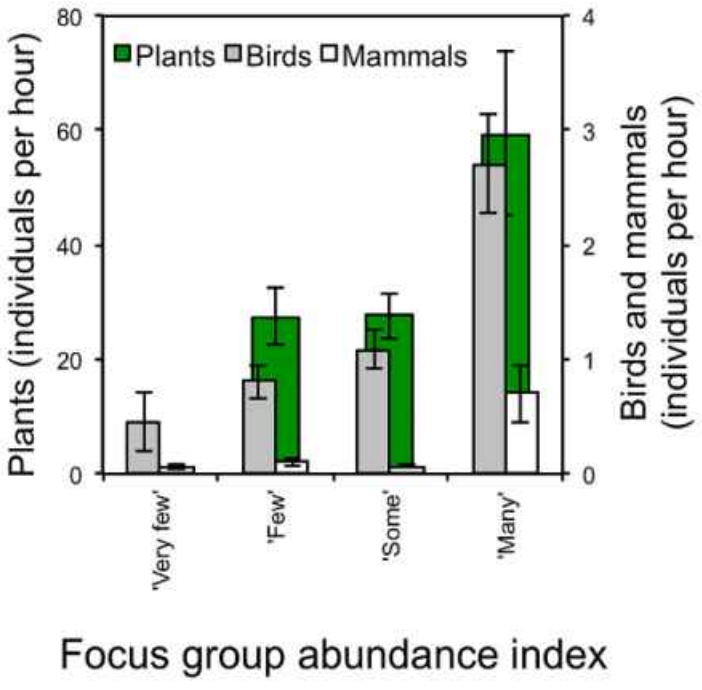

Figure 9. Relationship between community member focus groups' statements of abundance of 10 plant, bird and mammal forest resources and the average abundance indices (number of individuals observed per hour, with S.E.) of the same resources obtained by community members' and trained scientists' transect walks between 2007–2009 at nine study sites in the Bosawás Biosphere Reserve, Nicaragua (XV). The diagram is based on 430 tripled records from focus groups, trained scientists and community member transects of the same resources in the same sites and at the same time (same three-month period).

Experienced community members' perceptions of forest resources, transmitted orally during focus group discussions, compared well with line transect results by scientists. My findings on the consistency of community assessments of resource abundance and trends relative to surveys by trained scientists concur with previous studies in forested habitats of developing countries where there were no differences in scale, place and time of the survey effort by community members and scientists (XIV; XV). Studies that reported contradictions between community members and scientists had mismatches between the temporal and spatial scales, timing, and/or geographical area, which might have influenced these comparisons.

Overall, my five evaluations of the quality of information from locally-based approaches to natural resource monitoring suggest that locally-based approaches whether sampling-based or perception-based are capable of providing high-quality information as long as community members are committed and they have the appropriate tools. I found that even in locally-based natural resource monitoring systems existing in the 'real world', outside of a research context, community members and trained scientists produced closely similar results on status of and trends in species and natural resources (X; XI; XIV). I found no evidence of an inverted relationship between accuracy and community member participation (VIII) across the spectrum of natural resource monitoring approaches.

4.2 Challenges and opportunities related to the quality of information

Although my findings from five studies in ten countries suggest that measurements by community members can compare well with closely similar measurements by scientists, nevertheless locally-based approaches to monitoring are in general likely to be more vulnerable than professional techniques to various sources of bias, which decrease their accuracy (defined as the closeness of the resulting measures to their true values; Table 4a). Key potential problems include a lack of measurement experience on the part of observers (which often leads to over- or under-estimates of abundance and size); potential conflicts of interest (with recorders perhaps inadvertently providing data which are biased towards managers' preconceptions); a tendency, in the absence of careful documentation, for methods to drift over time, or for results to reflect long-term ('fossilized') perceptions more than current trends; and the potential for the spatial or temporal coverage of monitoring to be unrepresentative of the entire system of interest (IV).

Besides accuracy, the utility of monitoring is limited by the precision of the results (that is, the closeness of repeated measures of the same quantity to each other; Table 4b). Sources of low precision (leading to high variance around the estimated true value of the attribute of interest) may include small sample sizes; overly thin or patchy temporal or spatial deployment of sampling effort; the physical loss of data; and the inconsistent application of methods, either through time or across observers. These problems can affect all perception- and sample-based monitoring but are likely to be a particular problem where financial or professional human resources are tightly limited (IV).

Table 4. Key potential constraints to the accuracy and precision of locally-based and scientist-executed natural resource monitoring (IV).

	Locally-based monitoring	Scientist-executed monitoring
(a) Constraints to accuracy		
Lack of measurement experience	2	1
Conflict of interest	3	1
Inconsistent use of methods, across time or observers	3	1
”Fossilized” perceptions	1-2	0
Unrepresentative spatial or temporal spread of sampling effort	1-3	1
Poor identification, field or language skills	1-3	1-3
(b) Constraints to precision		
Small sample size	3	2
Poor temporal or spatial spread of sampling effort	1-3	1
Physical loss of data	2	1
Inconsistent use of methods, across time or observers	3	1

0 = not a problem; 1 = limited problem; 2 = potentially important problem; 3 = potentially serious constraint

In my five studies of the quality of information from locally-based approaches to natural resource monitoring, there was no known major conflicts over resources in any of the areas studied. In situations in which an abundance of resources may condition quotas or financial payments to communities, the local communities may have an incentive to report false positive trends in those natural resources so that they can continue to harvest the resources or to be paid, even though the resources may actually be declining (XIV). Periodic triangulation of the monitoring results will therefore be required although this is no different to any well-designed natural resource management initiative, whether the monitoring is implemented by communities, the government or the private sector (Lund 2014; XI).

Triangulation could be based on random spot checks in which a subset of the area is resampled using other monitors or other field methods (e.g., remote sensing of forest cover). It could also be combined with a statistical analysis of the community-based data in order to search for anomalies or trends that are beyond the normal or expected range (Bird et al. 2014; XI). Of those approaches examined here, the locally-based approach most susceptible to bias is the focus group discussion because perception-based information are memorized and easily lost (Jones et al. 2008). In Table 5, I propose a number of measures that can be taken in order to reduce bias. For sampling-based local monitoring approaches an important measure to reduce bias is to allocate individuals with rank based on their knowledge, allowing data to be disaggregated according to this ranking.

Table 5. Recommendations on how to increase the ability of community member focus groups to provide natural resource abundance data that trained scientists would consider reliable (XV).

1. Establish independent focus groups in multiple communities that know resource abundance in the same geographical area (triangulation across communities)
2. Convene regular, e.g. annual, village meetings to present and discuss data and interpretation and obtain feedback from the entire community (triangulation across community members); guideline in XXII
3. Facilitate the collection of auxiliary data through, e.g. community members' direct counts of resources in the same area (triangulation across methods)
4. Include individuals within the focus groups who are themselves directly involved in using and observing natural resources (thereby increasing the number of primary data providers)
5. Use unequivocal categories of resource abundance
6. Ensure that the moderator of the focus group discussions has skill and experience in facilitating dialogue

Chapter 5.

Livelihood and biodiversity impacts of Natural Resource Monitoring

The third and final hypothesis I address is that *'locally-based approaches to natural resource monitoring provide a higher return on investment in terms of livelihood and biodiversity impact than alternative approaches to monitoring environmental change'*. I expected that locally-based approaches would be quicker at leading to livelihood and biodiversity impact than similar investments in conventional approaches. Livelihood and biodiversity impact is difficult to measure by a standard scale across different habitats, and the true impact may only be discernible in the long term (XIX). I therefore used natural resource management interventions as a proxy for livelihood and biodiversity impact.

I defined a 'natural resource management intervention' as a purposeful action by a managing body to conserve or achieve a more sustainable use of the natural resources (XIX). Examples include the development of bylaws at village and municipal level, local time and area closures for natural resource extraction, and restrictions on specific resource extraction methods and gear (II). Some times, data indicate that environmental conditions are stable or improving, and this would not usually lead to any management intervention (XVIII). While a management intervention is not an ideal measure of livelihood and biodiversity impact, it may be useful from a natural resource management perspective because it encourages a holistic approach whereby monitoring is seen as an integrated aspect of management. The 'management intervention' unit is close to the end-point: sustainable resource use on-the-ground. Management interventions are, however, impossible to track through deskwork but require concerted efforts by experienced people in the field. My experiences suggest, however, that it is useful to track management interventions because they can indicate the possible management impact of the system and, at the same time, provide direction.

I led a process where we recorded many different types of natural resource management interventions in locally-based monitoring systems in Greenland, Tanzania and the Philippines. In the monitoring system in Greenland, within the first three years of operation, it had led to 14 distinct recommendations for 12 natural resources in the four communities that were involved (X). These proposals related, for instance, to conservation of marine habitat, influencing marine harvest techniques and influencing goose harvest pressure (XVII), and they would require action by the community members themselves, the local municipal authority (e.g. municipal bylaws), the central government (e.g. the setting of quotas), or by other institutions.

Likewise, in the locally-based natural resource monitoring system in Tanzania, 181 natural resource management interventions were proposed by the community members as a result of the monitoring after just ten months of operation in 23 communities (VIII). Of these communities, 21 had suggested management interventions that targeted what scientists had independently identified as the most important threats to their respective forests. Seventy-five percent of interventions targeting the most important threats had been implemented at the time of the assessment, while most of the others were awaiting approval by district authorities.

While these examples strongly suggest that locally-based approaches to natural resource monitoring are effective in generating natural resource management interventions, they do not show how these systems would compare with conventional monitoring approaches without community involvement. I was however able to compare the return on investment in terms of natural resource management interventions of locally-based and conventional biodiversity monitoring methods in eight Philippine protected areas (XVIII). To my knowledge this was the first time anybody had systematically compared natural resource management interventions emanating from locally-based and conventional approaches to natural resource monitoring. The two sets of monitoring approaches were compared across 1.1 million ha of protected areas. One set comprised two methods that included 350 local people in data collection and/or discussion of data. These methods were the focus group discussion method and the field diary method (I; XXII). The other set of methods was composed of standardized techniques that follow normal scientific requirements for objectivity and repeatability. These methods were fixed-point photography and the line transect method. The methods were carried out by protected-area staff without the involvement of local communities. Natural resource management interventions undertaken over a 2 year and 7 month period were included. Before the monitoring system was established, the monitoring activity of protected area staff was largely restricted to regular assessment of the amount of extracted timber. Very few, if any, management interventions emanated from this.

I led a process where we compiled data on natural resource management interventions and reviewed written documentation on these at two national workshops on monitoring with protected-area staff and during 62 field visits. In addition, we reviewed 316 protected-area council resolutions and 60 quarterly reports from local to central government for natural resource management interventions.

Our data on natural resource management interventions show that, for approximately the same recurrent government investment, far more interventions result from participatory biodiversity monitoring methods than conventional scientific ones (Fig. 10a). This pattern also holds if we restrict the analysis to those interventions that only target the three most serious threats to species populations and habitats at each site (Fig. 10b). Moreover, if we look at interventions that led to policy change with a potential long-term impact on sustainable development (i.e. new resolutions or bylaws), the same pattern emerges (Fig. 10c). This general difference held true whether we considered resources used by local people or by outsiders (Fig. 10a-c). Our data suggest that participatory monitoring cost-effectively generates natural resource management interventions not only to address resource use by locals but also by people from other places.

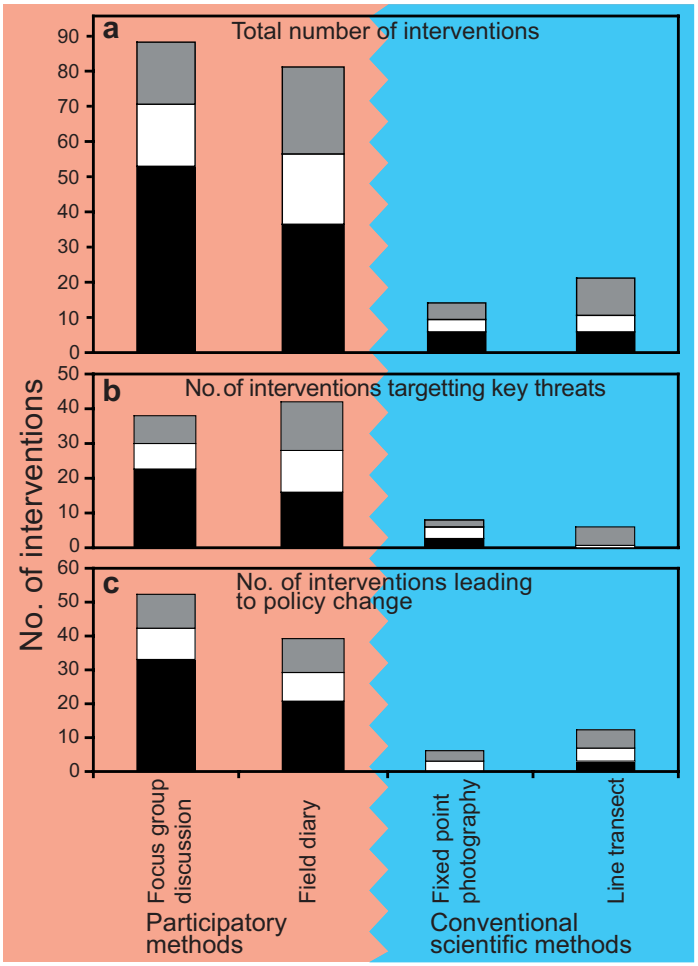

Figure 10. Effectiveness of participatory and conventional scientific biodiversity monitoring methods in generating natural resource management interventions intended to improve the way local people (black), outsiders (white), and both (grey) manage Philippine protected-area resources (n = 156 natural resource management interventions; XVIII). (a) The total number of interventions generated by each method. (b) The number of interventions that targeted the three most serious threats to the biodiversity of each site. (c) The number of interventions that led to policy change within local government and community institutions.

These results suggest that, from a government perspective, locally-based biodiversity monitoring is more effective than conventional monitoring in terms of generating local natural resource management interventions in Philippine protected areas. The interventions seemed to be relevant for biodiversity conservation because a large proportion addressed the most serious threats to the biodiversity of the sites (Fig. 10b) and led to changes in local policies with potentially long-term impacts (Fig. 10c).

The average time from sampling to decision-making was only 97 days (for the 154 interventions with available data), probably because most interventions (82%) were initiated by the same people and institutions that had compiled the underlying data, bypassing potential government bureaucracy (XIX). Many of the interventions were jointly undertaken by community members and the management authorities or consisted of local bylaws in support of protected area management. The monitoring led to more diversified and realistic management responses on the part of the

authorities, including a more socially-acceptable and effective approach to enforcement (XIX). Of the four field monitoring techniques used, the most participatory one generated most interventions aimed at ensuring a continued resource supply for local communities ($\chi_3^2 = 69.1$; $P < 0.01$). The interventions targeted, directly or indirectly, all known globally threatened species of mammals, birds and butterflies in the eight protected areas.

These results may, however, be context-dependent and not applicable in other countries (Rodríguez 2003). To examine the external validity (generalizability) of our findings from the Philippines, I initiated a meta-analysis of published natural resource monitoring systems to assess whether participation in data collection and analysis in monitoring systems influenced the speed and scale of decision-making and action. This was the first time that the speed and scale of decision-making and action emanating from natural resource monitoring had been examined quantitatively across a spectrum of natural resource monitoring systems with varying relative contributions of local stakeholders and professional researchers. I led a process where a total of ≈3,400 papers presenting published monitoring results were reviewed and a database of 104 publications on natural resource monitoring systems that described the role of scientists and local stakeholders in the monitoring was developed (XX). We identified who made decisions based on the results of the monitoring, and assessed the minimum time from the start of the data collection to the findings being used for decision-making.

I found that the degree of involvement by local stakeholders in natural resource monitoring profoundly influences the spatial scale and speed of decision-making based on the monitoring data (Fig. 11). The greater the involvement of local people in monitoring activities, the shorter the time it takes from data collection to decision-making following monitoring ($P < 0.001$). Two types of participatory monitoring are recognized: one where local people collect data but the analysis is done by someone else (categories C and D in our typology of natural resource monitoring systems), and another where local people collect and analyze the data themselves (categories A and B monitoring systems). The most locally-based and participatory of these two options leads to management decisions, which are typically taken at least three to nine times more quickly than scientist-executed monitoring, although they operate at much smaller spatial scales ($P < 0.001$; Fig. 11). Scientist-executed monitoring informs decisions in regions (44%), nations (38%) and international conventions (18%) ($n = 45$ scientist-executed systems).

My findings from the meta-analysis corroborate my previous observations that locally-based monitoring and professional monitoring lead to substantially different kinds of decisions (IV). Decisions from locally-based monitoring are often taken promptly and at the local level (Kerr et al. 1994), in response to immediate threats to the environment. These decisions usually result in actions based on community rules and enforcement, such as local bylaws governing resource use (van Rijsoort & Jinfeng 2005). Such actions are aimed not only at protecting habitats and/or species but also at ensuring a continued supply of benefits for the local human communities (VII). The decisions are often respected by the locals and the associated actions are relatively sustainable, both financially and organizationally (XIX), probably because they are nested within existing local institutions (Becker et al. 2005).

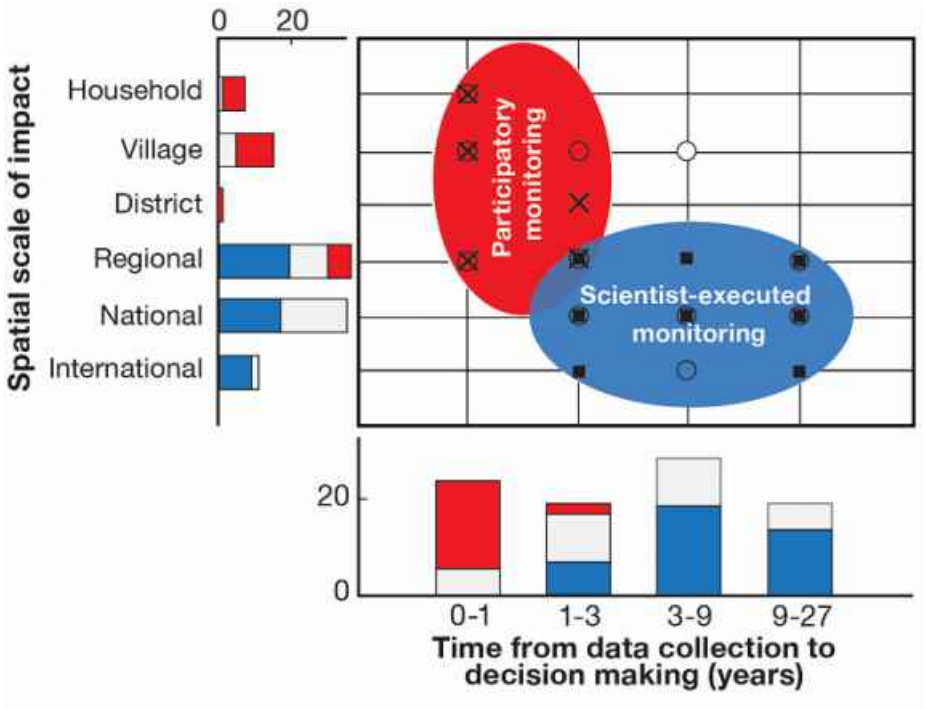

Figure 11. Decision-making from natural resource monitoring based on data from published monitoring systems 1989-2009 (n = 104; XX). ■, scientist-executed monitoring systems (n = 45); ○, monitoring systems with local data collectors (n = 37); and ×, participatory monitoring systems (n = 22). The circles comprise all the scientist-executed (blue) and all the participatory monitoring (red) systems. The bar chart indicates the number of scientist-executed monitoring systems (blue bars), monitoring systems with local data collectors (white bars) and participatory monitoring systems (red bars) at each level of spatial scale and implementation time.

This kind of monitoring generally provides fast and meaningful feedback to inform adaptive management (Walters & Hilborn 1978). In comparison, monitoring by scientists may be slow in leading to decisions but the scale of decision may be very different (IV). Professional monitoring has the potential to influence national and global policies and funding flows. Scientists often have better access to high-level decision-makers than local communities. For instance, results from locally-based monitoring are unlikely to persuade the US government to ratify the Kyoto Protocol, whereas findings from professional monitoring potentially could. Decisions from locally-based monitoring will generally not have impacts beyond the local scale unless the locally-based monitoring is embedded within or linked to a national or international scheme that feeds the data up to the levels at which governments, international agencies and multi-national corporations operate (VII).

Why does locally-based monitoring lead to locally-based decision-making? Based on my experiences, I suggest there are three reasons (IV). Firstly, unlike monitoring by scientists, participatory monitoring encourages decision-making by providing an institution (e.g. village discussion groups composed of particularly knowledgeable villagers) or a forum (e.g. meetings between rangers and local residents) for regular discussion of local natural resource management. Monitoring provides a reason to discuss better ways of managing resources. Secondly, participatory monitoring provides local residents with otherwise rare opportunities for collaboration with

government staff and for representation in local decision-making on natural resources. Understanding the local ways of thinking, and of making decisions, is therefore important for the success of local systems. Thirdly, decision-making based on local monitoring, is not swamped by government bureaucracy, because many of the decisions are taken promptly by the same people or institutions that collect the data (XIX).

In conclusion, my findings suggest that promptness of decisions emanating from monitoring is a characteristic of locally-based approaches to natural resource monitoring (VI). The general pattern I found in the Philippines (XVIII) also held true when I looked at published monitoring systems from across the world (XX). My literature analysis suggested that decisions from locally-based approaches tend to be taken at the local, operational levels of resource management, where they involve the people who face the daily consequences of environmental changes.

These results – together with those presented in chapters 3 and 4 – provide preliminary evidence in support of my overarching theory that locally-based approaches to natural resource monitoring can provide a mechanism for empowering local people while providing high-quality information, and that they can provide a higher return on investment in terms of livelihood and biodiversity impact than alternative approaches to monitoring environmental change.

Locally-based natural resource monitoring systems by definition cannot be established without any community involvement (Chapter 2). It is therefore difficult or impossible to find out if the effects of the locally-based natural resource monitoring systems on empowerment (Chapter 3) and livelihood and biodiversity (Chapter 5) are associated with the community members' feelings of ownership of the monitoring or with some other inherent aspects of the monitoring methods. Locally-based natural resource monitoring systems do, however, use methods and approaches that are likely to generate feelings of ownership (Chapter 1). Moreover, the monitoring systems' effects on empowerment, livelihoods and biodiversity correspond with the effects that are expected from current behavioral and organizational theories on psychological ownership (Pierce & Jussila 2011).

Chapter 6.

Future potential

Locally-based approaches to natural resource monitoring have considerable potential for improving understanding of environmental changes as well as for improving the management of natural resources (XIV; XV). 'Citizen scientists' may be the only feasible way to understand the changes on the planet at fine enough spatial resolution and with enough sample points to build credible models of those factors that cannot be measured by remote sensing (Huntington 2011; Dickinson & Bonney 2012; Haklay 2013; Cooper et al. 2014; Mitchard et al. 2014). If this potential for improving understanding of environmental changes is to be fulfilled, it will however require that natural resource monitoring schemes are designed so that experienced community members are motivated to participate in the monitoring. It will also require that the community members are able to reach a consensus on commensurable parameters, and that they will be willing to share their data and information.

Across large parts of the world, decision-making has been decentralized to operational levels of management, including to local communities (Agrawal et al. 2008). Monitoring management outcomes at the local level therefore becomes vital to resource management (Chhatre & Agrawal 2009; Luzar et al. 2011). Moreover, involving community members in resource monitoring helps link that resource monitoring to decision-making at the operational level of resource management and, therefore, has the potential to become a major contributor to global sustainable development strategies (XIV; XX). This is particularly relevant as the world struggles (1) to link environmental performance to payment schemes (Jack et al. 2008), (2) bringing indigenous and local knowledge systems into the science–policy interface (UNEP 2012a), (3) making informed decisions on management of living resources in a rapidly changing Arctic (Huntington 2011), and (4) linking international environmental agreements to decision-making in the 'real world' (Jones et al. 2011).

Below I discuss the potential of locally-based approaches in each of these four areas where locally-based approaches to natural resource management are particularly relevant. Locally-based natural resource monitoring has also potential in environmental-health efforts as central element of early warning systems for zoonotic diseases where prompt detection can prevent outbreaks (e.g. Ebola; Alexander et al. submitted) but I have not had an opportunity to investigate this. Below I will also present criteria for choosing an appropriate natural resource monitoring system for a given context – and suggest recommendations for the design of locally-based natural resource monitoring systems.

6.1 Locally-based approaches in 'Payment for Ecosystem Services' programs

One group of international conservation initiatives offers financial payments to local communities living in biologically-rich areas as compensation for their willingness to regulate or reduce their use

of globally significant natural resources. Such 'payment for ecosystem services' (PES) programs include the UNFCCC Reducing Emissions from Deforestation and Forest Degradation mechanism (Mertz et al. 2012; UNFCCC 2012) and more local PES schemes, for example, for water (Fisher et al. 2010) or wildlife (Sommerville et al. 2011). These programs rely on frequent monitoring on multiple scales to facilitate decision-making and to assess whether communities have met established conservation benchmarks and have thereby earned financial or other rewards (Skutsch 2011; XIV).

Local community involvement in monitoring PES schemes can enhance feasibility, efficiency and potential equity benefits (Sikor 2013; XIII). I have examined, for the first time, to what extent locally-based monitoring has been taken up in existing Reducing Emissions from Deforestation and Forest Degradation (REDD+) programmes in the 'real world', outside of a research context (XIII). I found that although community involvement in REDD+ receives much attention in the international negotiations on REDD+ policies it is not widely implemented. There is a gulf between UNFCCC texts on involving communities and field implementation realities.

Together with Dr Margaret Skutsch I have developed a preliminary protocol to help decide whether the key conditions are in place for applying and sustaining local REDD+ forest biomass monitoring (Table 6). For instance, it will be uneconomic to include very small forest areas as the costs of monitoring outweigh the possible market value of the carbon credits generated. The communities themselves would lose out (XII). Likewise, in some areas there is a potential risk posed to the locals from being involved in forest monitoring. It is unlikely that local REDD+ monitoring will be successful in those areas. Further work is however needed to verify these variables on-the-ground.

Table 6. Protocol to help decide where community member REDD+ monitoring of forest biomass is appropriate (XI).

Who	Positive attributes
The local community	• Experience in communal management of natural resources • Evidence of trusted community organization and leadership • Residents show interest in sustainable forest management • Residents utilize forest resources • Clear rights over forest resources are present in practice
The government	• Government policy is in place for shared management of resources with communities • Community forest management has been adopted as a strategy within the national REDD+ programme, and attendant procedures and rules are clear (e.g. on benefit distribution to directly affected communities, and verification) • National database for carbon stock accounts will accept data generated by communities at the local level
The intermediate organization	• Presence of suitable and interested intermediate organizations with experience of working with communities, within reasonable distance of the forests concerned
The forest area	• Minimum forest unit size of around 100 ha needed to break even on transaction costs of measurement • Evidence that community management will ensure tree growth and continued presence of the forest • No recent history of major conflicts, violence or threats reported by forest managers or communities

6.2 Locally-based monitoring approaches for connecting knowledge systems

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) was established in 2012 by 94 Governments, and by August 2014 had 121 Government Members. One of its functions is to produce assessments of the state of the planet's environment, while "recogniz(ing) and respect(ing) the contribution of indigenous and local knowledge" so as "to bring (the) different knowledge systems, including indigenous knowledge systems, into the science-policy interface" (UNEP 2012a). This intention will entail the articulation of indigenous and local knowledge (UNEP 2011; 2012b; Turnhout et al. 2012).

A key challenge for IPBES will therefore be how to use information generated by different knowledge systems (Huntington 1998; Colfer et al. 2005) within synthetic assessments at the science-policy interface (Sutherland et al. 2014). While scientific knowledge is validated primarily through peer-review, other knowledge systems have different validation approaches (Tengö et al. 2014). Validation of information within knowledge systems is well-established, whereas validation across knowledge system is a major challenge (Tengö et al. 2014). Unidirectional scientific validation of other knowledge systems may compromise the integrity and complexity of the knowledge (Bohensky & Maru 2011; Gratani et al. 2011) and promotes power inequality between technocrats and communities (Nadasdy 1999; Bohensky et al. 2013). Alternatively, validation of community-based knowledge through a respectful process of collaboration between scientists and community members facilitates mutual learning and empowerment (Cullen-Unsworth et al. 2012).

About 370 million indigenous people live on earth — from the tropics to the poles, and include some of the world's poorest and most marginalized communities (United Nations 2009). To participate in decision-making, indigenous people need to translate a wellfounded knowledge base on their territories (Dallman et al. 2011; UNEP 2013) into a format where it can be heard (Ens et al. 2012).

I led a process where we tested the potential role of simple community-led focus groups to connect indigenous/local and scientific knowledge systems. I found that using community-led focus groups to document and validate indigenous and local knowledge on natural resources could increase the information available for measuring status and trends in natural resources, while at the same time potentially contributing to the empowerment of indigenous and local communities in natural resource management (XV).

While I believe this approach has great potential, the use of community-led focus groups for connecting knowledge systems should not be rolled out uncritically. Information 'harvesting' must be avoided (Gamborg et al. 2012; Tengö et al. 2014). Representatives of indigenous and local communities should decide whether focus groups on resource abundance can help enable them be heard and be useful for documenting and validating knowledge. This is in line with the UN Declaration on the Rights of Indigenous Peoples which states that development must take place in accordance with their 'Free, Prior and Informed Consent' (United Nations 2008).

Promoting locally-based approaches to natural resource monitoring could be an important element of the work of the IPBES as it seeks to fulfil its mandate to recognize and respect the contribution of indigenous and local knowledge (UNEP 2012a). While IPBES is widely recognized as an assessment process, and needs to draw on information from multiple sources, it also has three other functions: promoting the generation of knowledge; delivering policy support tools and methodologies; and capacity building. IPBES therefore has a potentially strong role to play in promoting the use of new approaches that allow the improved capture of data and information, in promoting the means for bringing data and information from different knowledge systems together, and in building the capacity to do both. Locally-based approaches to natural resource monitoring is therefore an important area of work to be developed more formally within the framework of IPBES assessments, not only to feed into the IPBES assessments themselves but so that such approaches are used at all levels.

6.3 Locally-based approaches for monitoring the rapidly changing Arctic

The climate is rapidly changing and the people in the Arctic are facing huge challenges (Oskal et al. 2009; Post et al. 2009; Krupnik et al. 2010). Many rely on natural resources for both subsistence and income (Dahl 2000; Nuttall 2005; 2009). The Greenland Government has piloted the development of a simple, field-based system for monitoring and managing resources developed specifically to enable Greenlandic fishers and hunters to document trends in living resources and to propose management decisions themselves (X; XVII). The system was designed to build upon existing informal observing methods and it includes most of the aspects that are believed to make knowledge generation initiatives 'culturally appropriate' (Pulsifer et al. 2011). At the national level in Greenland, there is considerable scope for collecting community member observations from this system and using them to track wider trends in the abundance of resources while at the same time increasing local people's input into higher-level decision-making. Data from local monitoring could potentially be aggregated to generate larger-scale overviews of, for instance, species range and phenology, habitat condition, opportunities and threats, the impacts of management interventions and the delivery of benefits such as wildlife resources to the local communities from the natural ecosystems.

For some species and populations locally-based approaches to monitoring are perhaps the only source of information (X). This is for example likely to be the case in Greenland for coastal populations of Atlantic Cod *Gadus morhua*; Arctic fox *Alopex lagopus*; some populations of caribou and musk ox *Ovibos moschatus*; snow goose; Canada goose; and white-tailed eagle *Haliaeetus albicilla*. Professional biologists' monitoring will, however, remain very much needed, for instance in determining safe thresholds for harvesting wildlife populations and providing other quantitative information on the abundance of resources where management requires 'exact' knowledge of population numbers. This holds true especially for Greenland white-fronted goose and breeding Brünnich's guillemot, which are both rapidly declining in numbers in central North West Greenland (Boertmann 2007; Labansen & Merkel 2012) as well as for polar bear *Ursus maritimus*, walrus *Odobenus rosmarus* and cetaceans, which are included in international management regimes where the boards rely on scientist-executed monitoring methods (Polar Bear

Specialist Group, North Atlantic Marine Mammal Commission, International Whaling Commission). Locally-based approaches to monitoring has the potential to provide a second informed opinion on these species (Born et al. 2008). It likewise has the potential to contribute important knowledge about trends in abundance, during periods when scientists are not monitoring.

A future national monitoring strategy in Greenland should therefore combine several monitoring methods, including conventional scientific methods and locally-based monitoring approaches (X). If the current local system were to be transformed into a national system for using local observations and knowledge to improve resource management in Greenland, it would require the establishment of strong linkages between the local and national data management systems. It would also require expanding the local monitoring to more communities, geographically spread across Greenland.

Experience from abroad suggests that the scope for linking local and national natural resource monitoring may best be explained by thinking about contributions and relative benefits (Pratihast & Herold 2011). If there are not benefits for both sides, the local-national linkages are unlikely to be sustained. On the other hand, if both sides contribute and benefit, a situation can be created that can help to stimulate and sustain collaboration. In Fig. 12, I conceptualize how communities could be linked to national monitoring in Greenland in a mutually beneficial way. If the current local system were to be transformed into a networked, national system, the central government would need to provide a policy that sets aside government staff time and funds, develop minimum requirements for local monitoring and establish a data infrastructure system so that locally-acquired data can be uploaded and made publicly-available subject to the approval of the data-providing community members. In return, local monitoring could encourage community engagement in decision-making and holistic approaches to resource management, and contribute data to national policy-making (Sutherland et al. 2014). Such efforts would, however, add costs to a system that is currently paper-based and low-tech and the only cost of which is the limited time of administrators at municipal and central government level.

While community-based documentation cannot replace scientists' monitoring of Greenland's natural resources, our experience suggests there is great potential for combining the two approaches (XVII). Both have roles to play and partnerships could only be beneficial (Huntington et al. 2004; Merkel 2010). If properly coordinated, local monitoring can provide information on those species and populations that matter most to fishermen, hunters and environmentally-interested community members (Johnson et al. in press). The resulting dialogue between local communities and authorities can facilitate a better differentiation of fishing and hunting periods and quotas geographically and help adjust the resource management to the changing environmental conditions. The dialogue can also lead to a common understanding of local natural resource use and an increased ownership and acceptance of regulatory actions, whether implemented by the local or the national level.

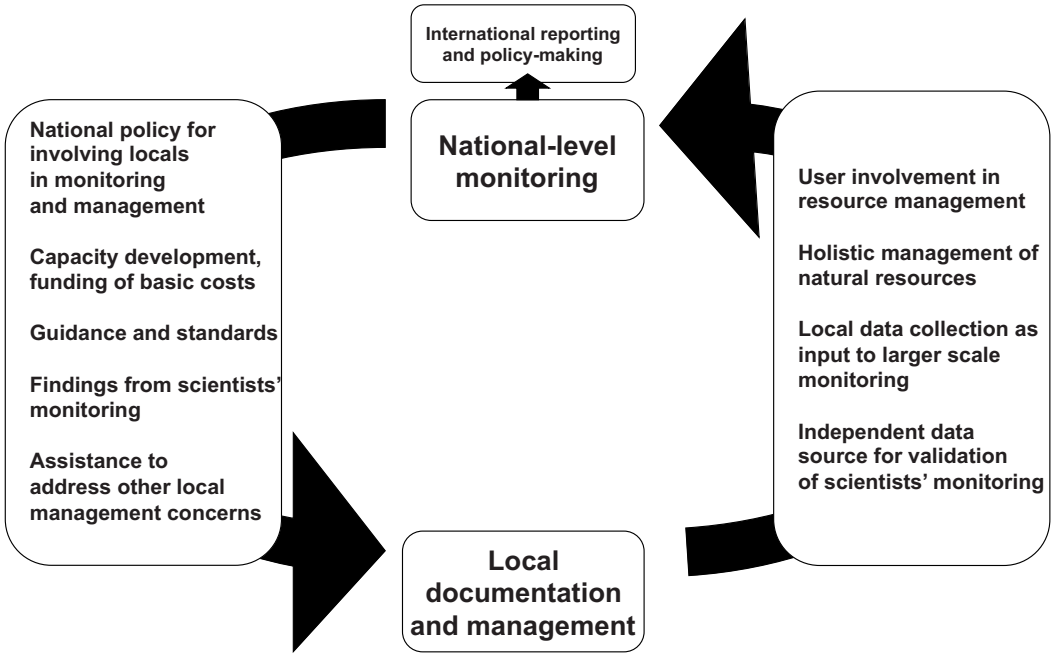

Figure 12. Contributions to, and benefits of, local monitoring for national-level monitoring of natural resources in Greenland (X; adjusted from Pratihast & Herold 2011, with permission).

6.4 Locally-based approaches for reinforcing international agreements

Jones et al. (2011) proposed that the most important global environmental monitoring objectives should be: (1) to evaluate conservation management actions; (2) to inform policy choices; and (3) to raise awareness among the public and policy makers of sustainable development. Meeting these objectives requires careful choice of environmental indicators and a clear understanding of the best ways of collecting data to populate them. A major challenge for delivering international environmental and developmental agreements is that of linking the agreements to decision-making on the management of natural resources in the 'real world'. Past lessons suggest that the use of 'lay' knowledge can help governments and civil society address environmental problems at an early stage (Harremoës et al. 2001). Involving community members in monitoring the environment can not only raise awareness among the public and policy makers about sustainable development (e.g. Wals et al. 2014; IX) but also – crucially – enhance management responses and improve the speed of decision-making to tackle environmental trends at operational levels of resource management (Tidball & Krasny 2012; XVIII; XX).

My assessment of data gathering possibilities for all indicators of 12 major international environmental and developmental agreements demonstrates for the first time that, under the present work plans of many international agreements, there is considerable scope for involving local stakeholders in collecting relevant data (VII). Community member involvement in data collection has the potential to help international agreements raise awareness among participants at local,

national and international levels. Efforts to mobilize and maintain a large community-based initiative can, however, be costly and time-consuming. Some indicators are best suited to expert-driven assessment. Great care is therefore needed when developing indicators.

A few agreements, such as the Ramsar Convention on Wetlands of International Importance, already use thousands of volunteers around the world to collect the required data on bird populations (Kuijken 2006), which helps to populate the 'status and trends of waterbird biogeographic populations' indicator (Ramsar Convention on Wetlands of International Importance; VII). In addition, eBird, a project managed at the Cornell Lab of Ornithology, now collects more than 5 million checklists of birds from observers around the globe each month that can be used in a variety of indicators focused on bird populations (Sullivan et al. 2014). Likewise, a network of volunteers monitors coral reefs worldwide to collect the data required to populate the Convention on Biological Diversity (CBD) indicator 'anthropogenic pressures on coral reefs […] are minimized so as to maintain their integrity and functioning' (Word Fish Center 2008).

Promoting locally-based approaches could significantly enrich the monitoring of progress towards the indicators of the CBD and many other global conventions. It would also link environmental monitoring to awareness-raising and enhanced decision-making at all levels of resource management.

6.5 Criteria for choosing a monitoring system

Locally-based natural resource monitoring has been demonstrated to be suitable for monitoring organisms or phenomena that are meaningful to community members – for example, as a source of food or income or of cultural or spiritual value (XIV; XV). However, if the aim is to monitor attributes that are not relevant from a local perspective (examples in VII, its Table 4), locally-based natural resource monitoring may not be suitable. This is important to consider for any locally-based monitoring system.

When choosing a monitoring approach for a monitoring system, the context and the aims of the initiative will thus define which systems are most appropriate (Table 7). Scientist-executed monitoring (category E) systems can be executed almost anywhere because they are largely externally driven. They are most suitable where highly technical monitoring across large scales demands high levels of professional expertise and where there is a guaranteed source of funding that will permit this form of technical monitoring to be sustained over time (Birkhead 2014).

Externally-driven monitoring with local data collectors (category D) can be used where there are skilled volunteers or funds to pay staff for collection of field data. These types of system are ideal when large numbers of people are required to collect data across wide geographical areas and on a regular basis. This capitalizes on the strength of gathering the most data possible, even if the accuracy or precision of each individual data point may not be as high as that obtained by highly trained professionals (VI).

Table 7. Criteria of importance when making decisions on which category of natural resource monitoring system is most suitable for a given circumstance [a]. The relative role of local stakeholders in the monitoring systems increases from bottom to top between the five categories of monitoring systems (VI).

Monitoring category [b]	Highly accurate data required from the monitoring system	Government/ civil society organization has budgets for monitoring with their own staff	Professional scientists available	Volunteers easily available	Government extension/ ranger staff available at local levels
A	*			**	
B	**	**	**	**	**
C	**	***	***	**	**
D	***	***	***	***	*
E	***	***	***		

Increasing role of local stakeholders

Monitoring category [b]	Area remote and difficult for outsiders to access easily	Natural resources an important part of local livelihoods	Current management regimes allow local people's involvement (e.g., in parks and reserves)	Policy and legal environment supportive of community involvement in resource management	Empowering local people to make decisions about natural resource use an important objective of management
A	***	***	***	***	***
B	***	***	***	***	***
C	***	***	**	**	**
D	**	*		**	
E					

Increasing role of local stakeholders

[a] Key ***, very relevant; **, relevant; *, sometimes relevant; blank, not relevant.
[b] Monitoring categories are defined in the text.

The locally-based approaches of categories B and C depend on local people making a significant investment in monitoring. They are therefore most appropriate: (1) where local people have significant interests in natural resource use; (2) when the information generated can have an impact on how one can manage the resources and the monitoring can be integrated within the existing management regimes; and (3) when there are policies in place that enable decentralized decision-making. In these systems, local ownership, empowerment and a link to management decisions can be even more important than data quality, although management and empowerment benefits should not be used as an excuse for poor design (VI). A balance is therefore needed between monitoring goals and the broader goals of seeing the results used and decisions taken about natural resource management. Autonomous local monitoring (category A) systems, by definition, cannot be instigated from outside.

I recommend that scientists and managers who would like to establish systematic locally-based monitoring of biodiversity and resource use employ the steps outlined in Box 3. The monitoring should be kept as simple and locally appropriate as possible (IV). Attention should be paid to

capacity-building of data gatherers in field techniques, species identification skills, and how to make use of the data. The monitoring should be institutionalised within existing management structures at both local and national level and preferably be embedded within a scheme that feeds the data up to national or international levels. Unnecessary changes in the monitoring should be avoided and, if it has to change, efforts should be made to nest previous scheme within new scheme. Management interventions resulting from the monitoring should be tracked as a possible indication of the scheme's management impact and to provide direction.

Box 3. Six steps for developing locally-based monitoring of natural resources (IV; modified from Royal Society 2003; Green et al. 2005; examples of monitoring system in I; X; manual in XXII).

1. Discuss within the responsible institutions and with interested stakeholders the need for, and the aims of, natural resource monitoring. In particular, discuss:

- Which aspects of natural resources are you interested in?
- What questions do you want the monitoring to answer?
- What are you likely to do with the results?
- When are the results of monitoring needed?
- What level of precision and accuracy is required?
- What incentives are required to ensure community engagement?

2. Use existing knowledge, including that of community members, to develop a model for the system, even if it is only conceptual. For example, the topic of interest may be the number of turtles that can be harvested sustainably from an area. This cannot be measured directly but developing a simple model of how this relates to measurements that are feasible and realistic for community members to conduct (such as the number of nesting females on a communal beach; Townsend et al. 2005) makes the limitations of the assessment explicit.

3. Agree on an institutional framework for using the results of monitoring for adaptive management.

- Agree on who takes decisions, and how monitoring results reach this body
- Develop and agree on the mandates and responsibilities of the involved parties
- Wherever appropriate, the monitoring should be embedded within existing institutions

4. Develop a sampling strategy that specifies who measures what, how, where and when.

- Discuss the usefulness, costs and difficulty of alternative measures, including any existing systems underway
- Identify which species, areas or resource uses are to be monitored
- Design a sampling strategy which pays explicit attention to potential sources of bias and in which the spatial and temporal deployment of sampling effort is appropriately stratified to maximize precision, given available resources
- Train data gatherers to follow a common protocol, which is written down; if guidelines and training materials from other monitoring systems are relevant, ask to use them, and adapt the materials to the local context
- Agree on how and where to store data
- Conduct a pilot study to test feasibility of data collection protocols; check with stakeholders whether the resulting data address their needs

5. Begin implementation on-the-ground. Important steps include:

- Store data in its most disaggregated form and with details of exactly how it was collected
- Record sampling effort, who collected the data, and precise locations of field study areas
- Keep raw data for checking and re-interpretation
- Ensure that checks are carried out to keep errors in recording and data storage at an acceptable level
- Analyze the data, and feed results back to data gatherers
- Wherever possible, compare results with those of other locally-based or professional approaches
- Provide results to decision-making body, and check they are fit for purpose
- Ensure that data gatherers are aware of management decisions arising from their data

6. Discuss the results with the local/national stakeholders and revise the strategy for the monitoring accordingly.

- Address sustainability issues such as post-project funding and recurrent training needs
- Keep track of management interventions resulting from the monitoring
- Make data available on open access database, if possible
- Facilitate the development of national policy, guidelines or tools for monitoring.

Chapter 7.

Recommended further work

Although considerable progress can be made towards improving the monitoring and management of the world's natural resources using existing results and experiences from locally-based approaches (IV; VI; XIII; XIV; XX), there are many areas where improvements and new information are still needed.

The rise in 'citizen science' needs a new and sophisticated scientific understanding (Bonney et al. 2014; VII). There is a need to develop the science that would enable the integration of different types of knowledge in a scientifically robust way in order to obtain a proper understanding of spatial and temporal trends at different scales (Kelling et al. 2009; Spiegelhalter 2014; XIV; XV). Likewise, there is a need to develop a sophisticated understanding of the uncertainties of monitoring, and build robust decision-making approaches that embrace these (O'Donnell et al. 2010; Bunnefeld et al. 2011; Milner-Gulland 2011; II; IV; XVII). This would require integrating hard core social science e.g. on understanding empowerment and institutional change, with hard core natural science on monitoring change, at a range of scales from the individual to the global.

The following five areas of study are recommended in order to explore the strengths and weaknesses of citizen science approaches to natural resource monitoring, elucidate its capabilities and limitations, compare with other scientific approaches (empirical to anthropological), and link to decision-making on scales of engagement ranging from communities to central government agencies:

1. **Motivation of global citizens**
   It would be desirable to have a better understanding of the motivation and needs of participating citizen scientists both in the developing and developed worlds (Lawrence 2010; IV; IX; X). A working hypothesis for this research could be that citizens participate in citizen science when empowered and when benefitting from monitoring activities.

2. **Employing novel technologies**
   There is a need to develop tools for global application, and to test approaches and data flows from communities to global decision-making and from global and national decisions to local action (Haklay 2013; I; IV; VI; VII; X; XIV; XV; XVII; XXI; XXII). A working hypothesis for this research could be that novel technologies such as, for example, data collection platforms running on smartphones and based on decision trees of pictorial icons have the capability to transform the relationship between scientists and global citizens.

3. **Accuracy and fitness for use**
   It would be valuable to examine the power to detect trends in a wide array of existing scientific to citizen science approaches, and make detailed comparisons between citizen and internet-sourced data and data collected in a more "rigorous or scientific" way (II; IV; VI; VIII; XVI; XVII; XVIII). A working hypothesis for this research could be that local community monitoring can measure trends of interest to natural resource management under realistic conditions of effort and resources, given appropriate approaches.

4. **Meta-analysis of data from locally-based monitoring**
   It would be useful to gather together large-scale locally-produced datasets to analyze macro-ecological questions and develop novel technologies for potential global application as data collection and verification tools (Hochachka et al. 2012; Hampton et al. 2013; VII; XIV; XV). A working hypothesis for this research could be that citizen science data, once harvested and harmonized from emerging sources such as, for example, novel web-based technologies, can be used to fill information gaps and improve our understanding of ecological communities in space and time.

5. **Mainstreaming and societal engagement**
   It would be desirable to research the co-production of science and policy, identifying strategies of engagement between scientists (including local community monitors) and decision-makers (Turnhout et al. 2012; Sutherland et al. 2014; Tengö et al. 2014; I; IX; X; XV; XVII; XVIII; XIX; XX). A working hypothesis for this research could be that the use of citizen science monitoring data can both improve conservation and livelihood outcomes at the local level and contribute meaningfully to global environmental assessments and international policy processes.

In combination, these proposed areas of further study will enable a comprehensive analysis of how locally-based approaches to monitoring work, why they work, what they can be used for, and what their strengths and weaknesses are (VII). Such analyses may fundamentally affect how macro-ecological, climate change, ecosystem service and economic systems models, will be built in the future. This would require a multidisciplinary team comprising experts from the anthropological, natural, economic, policy, and technological, sciences. Potentially, such a grouping of scientists could, however, deliver transformational change in the way the world monitors and manages natural resources.

References

Agrawal, A., Chhatre, A. and Hardin, R. 2008. Changing governance of the world's forests. *Science* 320: 1460–1462.

Alexander, K.A., Sanderson, C.E., Marathe, M., Lewis, B.L., Rivers, C.M., Shaman, J., Drake, J.M. et al. What factors might have led to the emergence of Ebola in West Africa? *PLOS Neglected Tropical Diseases* submitted.

Alder, D. and Synnott, T.J. 1992. Permanent sample plot techniques for mixed tropical forest. *Tropical Forestry Papers* 25: 1–124.

Baer, M. and Brown, G. 2012. Blind in one eye: How psychological ownership of ideas affects the types of suggestions people adopt. *Organizational Behavior and Human Decision Processes* 118: 60–71.

Becker, C.D., Agreda, A., Astudillo, E., Constantino, M. and Torres, P. 2005. Community-based surveys of fog capture and biodiversity monitoring at Loma Alta, Ecuador enhance social capital and institutional cooperation. *Biodiversity and Conservation* 14: 2695–2707.

Beddington, J., Asaduzzaman, M., Clark, M., Fernández, A., Guillou, M., Jahn, M., Erda, L. et al. 2011. *Achieving food security in the face of climate change: Summary for policy makers from the Commission on Sustainable Agriculture and Climate Change*. CGIAR Research Program on Climate Change, Agriculture and Food Security. CGIAR, Copenhagen.

Berkes, F. 2012. *Sacred Ecology*. Routledge, New York, 3rd ed.

Bibby, C.J., Burgess, N.D. and Hill, D.A. 2000. *Bird Census Techniques*. Academic Press, London, 2nd ed.

Bird, T.J., Bates, A.E., Lefcheck, J.S., Hill, N.A., Thomson, R.J., Edgar, G.J., Stuart-Smith, R.D. et al. 2014. Statistical solutions for error and bias in global citizen science datasets. *Biological Conservation* 173: 144–154.

Birkhead, T. 2014. Stormy outlook for long-term ecology studies. *Nature* 514: 405.

Blaikie, P., Brown, K., Stocking, M., Tang, L., Dixon, P. and Sillitoe, P. 1997. Knowledge in action: Local knowledge as a development resource and barriers to its incorporation in natural resource research and development. *Agricultural Systems* 55: 217–237.

Blomley, T. and Ramadhani, H. 2006. Going to scale with Participatory Forest Management: Early lessons from Tanzania. *International Forestry Review* 8: 93–100.

Boertmann, D. 2007. *Grønlands Rødliste 2007*. Danmarks Miljøundersøgelser and Greenland Home Rule, Nuuk, Greenland.

Bohensky, E.L., Butler, J.R.A. and Davies, J. 2013. Integrating indigenous ecological knowledge and science in natural resource management: perspectives from Australia. *Ecology and Society* 18(20).

Bohensky, E.L. and Maru, Y. 2011. Indigenous knowledge, science, and resilience: what have we learned from a decade of international literature on "integration"? *Ecology and Society* 16(6).

Bonney, R., Cooper, C., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K.V. and Shirk, J. 2009. Citizen science: A developing tool for expanding science knowledge and scientific literacy. *BioScience* 59: 977–984.

Bonney, R., Shirk, J.L., Phillips, T.B., Wiggins, A., Ballard, H.L., Miller-Rushing, A.J. and Parrish, J.K. 2014. Next steps for citizen science. *Science* 343: 1436 –1437.

Born, E.W., Heilmann, A., Kielsen Holm, L. and Laidre, K. 2008. *Isbjørne i Nordvestgrønland – En interviewundersøgelse om fangst og klima, 2006. Pinngortitaleriffik, Teknisk Rapport Nr. 70*. Grønlands Naturinstitut, Nuuk, Greenland.

Brofeldt, S., Theilade, I., Burgess, N.D., Danielsen, F., Poulsen, M.K., Adrian, T., Bang, T.N. et al. 2014. Community monitoring of carbon stocks for REDD+: Does accuracy and cost change over time? *Forests* 5(8): 1834–1854.

Brown, M. and Wyckoff-Baird, B. 1992. *Designing Integrated Conservation and Development Projects.* Biodiversity Support Program, WWF, Washington, D.C.

Buckley, P. 2009. *Ecotourism Principles and Practices*. Cambridge Univ. Press, Cambridge, UK.

Bull, A.T. 2005. Editorial. *Biodiversity and Conservation* 14: 3325–3326.

Bunnefeld, N., Hoshino, E. and Milner-Gulland, E.J. 2011. Management strategy evaluation: a powerful tool for conservation? *Trends in Ecology and Evolution* 26: 441–447.

Burke, P.J. and Reitzes, D.C. 1991. An identity theory approach to commitment. *Social Psychology Quarterly* 54: 239–251.

Burton, A.C. 2012. Critical evaluation of a long-term, locally-based wildlife monitoring program in West Africa. *Biodiversity and Conservation* 21: 3079–3094.

Butchart, S.H.M., Walpole, M., Collen, B., Strien, A.V., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M. et al. 2010. Global biodiversity: indicators of recent declines. *Science* 328: 1164–1168.

Cérdan, C.R., Rebolledo, M.C., Soto, G., Rapidel, B. and Sinclair, F.L. 2012. Local knowledge of impacts of tree cover on ecosystem services in smallholder coffee production systems. *Agricultural Systems* 110: 119–130.

Chhatre, A. and Agrawal, A. 2009. Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. *Proceedings of the National Academy of Sciences USA* 106: 17667–17670.
Coddington, J.A., Griswold, C.E., Dávila, D.S., Peñaranda, E. and Larcher, S.F. 1991. Designing and testing sampling protocols to estimate biodiversity in tropical ecosystems. Pp. 44–60 in (E.C. Dudley, Ed.) The Unity of 1704 Evolutionary Biology. *Proceedings of the Fourth International Congress of Systematic and Evolutionary Biology*, Dioscorides Press, Portland.
Colfer, C.J.P., Colchester, M., Joshi, L., Puri, R.K., Nygren, A. and Lopez, C. 2005. Traditional knowledge and human well-being in the 21st century. Pp. 173–182 in (G. Mery, R. Alfaro, M. Kanninen, M. Lobovikov, Eds.). *Forests in the global balance – changing paradigms* Vol. 17, IUFRO World Series. International Union of Forest Research Organizations, Helsinki, Finland.
Condit, R. 1995. Research in large, long-term tropical forest plots. *Trends in Ecology and Evolution* 10: 18–22.
Condit, R., Ashton, P.S., Manokaran, N., LaFrankie, J.V., Hubbell, S.P. and Foster, R.B. 1999. Dynamics of the forest communities at Pasoh and Barro Colorado: comparing two 50–ha plots. *Phil. Trans. R. Soc. Lond. B* 354: 1739–1748.
Constantino, P.A.L., Carlos, H.S.A., Ramalho, E.E., Rostant, L., Marinelli, C., Teles, D., Fonseca-Junior, S.F. et al. 2012. Empowering local people through community-based resource monitoring: a comparison of Brazil and Namibia. *Ecology and Society* 17(4): 22.
Cooper, C.B., Shirk, J. and Zuckerberg, B. 2014. The invisible prevalence of citizen science in global research: migratory birds and climate change. *PLoS ONE* 9(9): doi:10.1371/journal.pone.0106508.
Convention on Biological Diversity 2010. *Global Biodiversity Outlook*. UNEP, Montreal.
Csikszentmihalyi, M. and Rochberg-Halton, E. 1981. *The Meaning of Things: Domestic Symbols and the Self.* Cambridge Univ. Press, Cambridge, UK.
Cullen-Unsworth, L.C., Hill, R., Butler, J.R.A. and Wallace, M. 2012. A research process for integrating Indigenous and scientific knowledge in cultural landscapes: principles and determinants of success in the Wet Tropics World Heritage Area, Australia. *The Geographical Journal* 178: 351–365.
Dahl, J. 2000. *Saqqaq. An Inuit Hunting Community in the Modern World*. University of Toronto Press, Toronto, Buffalo, London.
Dallman, W.K., Peskov, V., Murashko, O.A. and Khmeleva, E. 2011. Reindeer herders in the Timan-Pechora oil province of Northwest Russia: an assessment of interacting environmental, social, and legal challenges. *Polar Geography* 34: 229–247.
Dallmeier, F. and Comiskey, J.A. (Eds.). 1998. *Forest biodiversity research, monitoring and modeling: Conceptual background and Old World case studies*. Parthenon Publishing, Paris.
Davis, J.H., Schoorman, F.D. and Donaldson, L. 1997. Toward a stewardship theory of management. *Academy of Management Review* 22: 20–47.
Devictor, V., Whittaker, R.J. and Beltrame, C. 2010. Beyond scarcity: citizen science programmes as useful tools for conservation biogeography. *Diversity and Distribution* 16: 354–362.
Dickinson, J.L. and Bonney, R. (Eds.). 2012. *Citizen Science: Public Collaboration in Environmental Research*. Cornell Univ. Press, Ithaca, New York.
Dipboye, R.L. 1977. A critical review of Korman's self-consistency theory of work motivation and occupational choice. *Organizational Behavior and Human Performance* 18: 108–126.
Ecological Society of America 2014. Dispatches. Locals beat scientists in biodiversity surveys. *Frontiers in Ecology and the Environment* 12: 428–432.
Eira, I.M.G., Jaedicke, C., Magga, O.H., Maynard, N.G., Vikhamar-Schuler, D. and Mathiesen, S.D. 2013. Traditional Sámi snow terminology and physical snow classification – two ways of knowing. *Cold Regions Science and Technology* 85: 117–130.
Ens, E.J., Finlayson, M., Preuss, K., Jackson, S. and Holcombe, S. 2012. Australian approaches for managing 'country' using Indigenous and non-Indigenous knowledge. *Ecological Management and Restoration* 13: 100–107.
European Community 2009. *Submission from the European Community to the UNFCCC Subsidiary Body for Scientific and Technological Advice, June 2009, on issues relating to indigenous people and local communities for the development and application of methodologies.* FCCC/SBSTA/2009/MISC.1. Available at http://unfccc.int/resource/docs/2009/sbsta/eng/misc01.pdf (visited August 4, 2014).
Everson, S. (Ed.). 1988. *Aristotle*, *The Politics* (c. 330 BC). Cambridge Univ. Press, Cambridge, UK.
Fisher, B., Kulindwa, K., Mwanyoka, I., Turner, R.K. and Burgess, N.D. 2010. Common pool resource management and PES: Lessons and constraints for water PES in Tanzania. *Ecological Economics* 69: 1253–1261.
Folke, C. 2004. Traditional knowledge in social-ecological systems. *Ecology and Society* 9(3): 7.
Fuller, J. 1998. Participatory monitoring of forest resources: current methodologies being developed in Thailand. *Rural Development Forestry Network* 23e: 23–27.
Furby, L. 1978. Possession in humans: an exploratory study of its meaning and motivation. *Social Behavior and Personality* 6: 49–65.

Gamborg, C., Parsons, R., Puri, R.K. and Sandøe, P. 2012. Ethics and research methodologies for the study of traditional forest-related knowledge. Pp. 535–560 in Parrotta, J.A. and Trosper, R.L. (Eds.). *Traditional forest-related knowledge: sustaining communities, ecosystems and biocultural diversity, World Forests*. Vol. 12. Springer, Netherlands.

Gardner, T.A. 2010. *Monitoring Forest Biodiversity: Improving Conservation through Ecologically Responsible Management.* Earthscan, London.

Gilchrist, G., Mallory, M. and Merkel, F. 2005. Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. *Ecology and Society* 10(1): 20.

Government of Madagascar 2008. *Submission from Madagascar to UNFCCC on the feasibility of involving local people in monitoring and assessment for REDD, June 2008*. Available at http://unfccc.int/resource/docs/2008/sbsta/eng/misc04a02.pdf (visited June 21, 2014).

Grandin, B. 1988. *Wealth ranking in smallholder communities: a field manual*. Intermediate Technology Development Group, London.

Gratani, M., Butler, J.R.A., Royee, F., Valentine, P., Burrows, D., Canendo, W.I. and Anderson, A.S. 2011. Is validation of Indigenous ecological knowledge a disrespectful process? A case study of traditional fishing poisons and invasive fish management from the Wet Tropics, Australia. *Ecology and Society* 16(3): 25.

Green, R.E., Balmford, A., Crane, P.R., Mace, G.M., Reynolds, J.D. and Turner, R.K. 2005. A framework for improved monitoring of biodiversity: responses to the World Summit on Sustainable Development. *Conservation Biology* 19: 56–65.

Groombridge, B. and Jenkins, M.D. (Eds.). 1996. *Assessing Biodiversity Status and Sustainability*. WCMC Biodiversity Series No. 5. World Conservation Press, Cambridge, UK.

Hayes, T. 2006. Parks, people, and forest protection: An institutional assessment of the effectiveness of protected areas. *World Development* 34: 2064–2075.

Haklay, M. 2013. Citizen science and volunteered geographic information – overview and typology of participation. Pp. 105–122 in Sui, D.Z., Elwood, M. and Goodchild, F. (Eds.) *Crowdsourcing Geographic Knowledge*. Springer, Berlin.

Hampton, S.E., Strasser, C.A., Tewksbury, J.J., Gram, W.K., Budden, A.E., Batcheller, A.L., Duke, C.S. and Porter, J.H. 2013. Big data and the future of ecology. *Frontiers in Ecology and the Environment* 11: 156–162.

Harmon, D. 1994. *Coordinating Research and Management to Enhance Protected Areas*. IUCN, Cambridge, UK.

Harremöes, P., Gee, D., MacGarvin, M., Stirling, A., Keys, J., Wynne, B. and Vaz, S.G. (Eds.). 2001. *Late Lessons from Early Warnings: The Precautionary Principle 1896–2000.* Environmental Issue Report 22. European Environment Agency, Copenhagen.

Hellier, A., Newton, A.C. and Gaona, S.O. 1999. Use of indigenous knowledge for rapidly assessing trends in biodiversity: a case study from Chiapas, Mexico. *Biodiversity and Conservation* 8: 869–889.

Hochachka, W.M., Fink, D., Hutchinson, R.A., Sheldon, D., Wong, W. and Kelling, S. 2012. Data-intensive science applied to broad-scale citizen science. *Trends in Ecology and Evolution* 27: 130–137.

Holt, B.G., Rioja-Nieto, R., Lupton, J. and Rahbek, C. 2013. Comparing diversity data collected using a protocol designed for volunteers with results from a professional alternative. *Methods in Ecology and Evolution* 4: 383–392.

Horwicz, A. 1878. *Psychologische Analysen auf phsiologischer Grundlage (Psychological Analysis of Physiological Foundation).* Faber, Magdeburg, Germany.

Howell, S. 2012. No rights — no REDD: The credibility gap between intention and execution. *Beyond Carbon: Enabling Justice and Equity in REDD+ Across Levels of Governance*, 23–24 March 2012, St. Anne's College, Oxford, UK. Available at http://www.eci.ox.ac.uk/redd/downloads/ppt/3-2-howell.pdf (visited June 4, 2014).

Hsu, A., Malik, O., Johnson, L. and Esty, D.C. 2014. Mobilize citizens to track sustainability. *Nature* 508: 33–35.

Huntington, H.P. 1998. Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge. *Arctic* 51: 237–242.

Huntington, H.P. 2011. The local perspective. *Nature* 478: 182–183.

Huntington, H.P., Callaghan, T., Fox, S. and Krupnik, I. 2004. Matching traditional and scientific observations to detect environmental change: a discussion on Arctic terrestrial ecosystems. *Ambio* 33: 18–23.

IBAMA 1998. *International workshop on biodiversity monitoring in federal protected areas: Observations and general remarks*. Available at www.erols.com/dsbaker/ (visited June 4, 2014).

International Institute for Environment and Development (IIED) 1992. Applications of wealth ranking. *Participatory Learning and Action* 15: 1–77. IIED, London.

Jack, B.K., Kousky, C. and Sims, K.R.E. 2008. Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms. *Proceedings of the National Academy of Sciences USA* 105: 9465–9470.

James, W. 1890. *The Principles of Psychology*. Holt, New York.

Jetz, W., McPherson, J.M. and Guralnick, R.P. 2012. Integrating biodiversity distribution knowledge: Toward a global map of life. *Trends in Ecology and Evolution* 27: 151–159.

Johnson, N., Alessa, L., Behe, C., Danielsen, F., Gearheard, S., Gofman-Wallingford, V., Kliskey, A. et al. The contributions of community-based monitoring and traditional knowledge to Arctic observing networks: Reflections on the state of the field. *Arctic* in press.
Jones, J.P.G., Andriamarovolona, M.M., Hockley, N., Gibbons, J.M. and Milner-Gulland, E.J. 2008. Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. *Journal of Applied Ecology* 45: 1205–1212.
Jones, J.P.G., Asner, G., Butchart, S.M. and Karanth, U. 2013. The 'why', 'what' and 'how' of monitoring for conservation. Pp. 329-343 in Macdonald, D.W. and Willis, K.J. (Eds.) *Key Topics in Conservation Biology 2*. Wiley-Blackwell, Oxford.
Jones, J.P.G., Collen, B., Atkinson, G., Baxter, P.W.J., Bubb, P., Illian, J.B., Katzner, T.E. et al. 2011. The why, what, and how of global biodiversity indicators beyond the 2010 target. *Conservation Biology* 25: 450–457.
Joppa, L.N., Visconti, P., Jenkins, C.N. and Pimm, S.L. 2013. Achieving the Convention on Biological Diversity's goals for plant conservation. *Science* 341: 1100–1103.
Kelling, S., Hochachka, W.M., Fink, D., Riedewald, M., Caruana, R., Ballard, G. and Hooker, G. 2009. Data-intensive science: A new paradigm for biodiversity studies. *BioScience* 59: 613–620.
Kerr, M., Ely, E., Lee, V. and Mayio, A. 1994. A profile of volunteer environmental monitoring: national survey results. *Lake and Reservoir Management* 9: 1–4.
Kinver, M. 2013. *Communities can monitor forests 'as well as experts'*. BBC News 29 Oct. 2013. Available at http://www.bbc.com/news/science-environment-24713215 (visited August 5, 2014).
Korman, A.H. 1970. Toward a hypothesis of work behavior. *Journal of Applied Psychology* 54: 31–41.
Kremen, C., Merenlender, A.M. and Murphy, D.D. 1994. Ecological monitoring: A vital need for integrated conservation and development programs in the tropics. *Conservation Biology* 8: 388–397.
Kremen, C., Raymond, I. and Lance, K. 1998. An interdisciplinary tool for monitoring conservation impacts in Madagascar. *Conservation Biology* 12: 549–563.
Krupnik, I., Aporta, C., Gearheard, S., Laidler, G.J. and Kielsen Holm, L. (Eds.) 2010. *SIKU: Knowing Our Ice. Documenting Inuit Sea Ice Knowledge and Use.* Springer Press, New York.
Kuijken, E. 2006. A short history of waterbird conservation. Pp. 52–59 in Boere, G.C., Galbraith, C.A. and Stroud, D.A. (Eds.) *Waterbirds around the World*. The Stationery Office, Edinburgh.
Labansen, A.L. and Merkel, F.R. 2012. Kolonien i Diskobugten i fare for udryddelse. *Sermitsiaq*, 11 May 2012.
Labonne, J. and Chase, R.S. 2009. Who is at the wheel when communities drive development? Evidence from the Philippines. *World Development* 37: 219-231.
Laidler, G.J. 2006. Inuit and scientific perspectives on the relationship between sea ice and climate change: the ideal complement? *Climatic Change* 78: 407–444.
Lawrence, A. (Ed.). 2010. *Taking Stock of Nature*. Cambridge Univ. Press, Cambridge, UK.
Lewis, M. and Brook, J. 1974. Self, other, and fear: Infants' reactions to people. Pp. 165-194 in M. Lewis and L.S. Rossenblum (Eds.) *The Origins of Fear*. Wiley, New York.
Locke, J. 1690. *Two Treatises of Government*. Awnsham Churchill, London.
Lund, J.F. 2014. Towards a more balanced view on the potentials of locally-based monitoring. *Biodiversity and Conservation* 23: 237–239.
Lund, J.F., and Saito-Jensen, M. 2013. Revisiting the issue of elite capture of participatory initiatives. *World Development* 463: 104–112.
Luzar, J.B., Silvius, K.M., Overman, H., Giery, S.T., Read, J.M. and Fragoso, J.M.V. 2011. Large-scale environmental monitoring by indigenous people. *BioScience* 61: 771–781.
Mace, G.M. 2014. Whose conservation? *Science* 345: 1558–1560.
Margoulis, R. and Salafsky, N. 1998. *Measures of Success: A Systematic Approach to Designing, Managing and Monitoring Community-Oriented Conservation Projects*. Adaptive Management Series, Biodiversity Support Program, Washington, D.C.
Margules, C.R., Austin, M.P., Davies, K.F., Meyers, J.A. and Nicholls, A.O. 1998. The design of programs to monitor forest biodiversity: lessons from the WogWog habitat fragmentation experiment. Pp. 183–196 in Dallmeier, F. and Comiskey, J.A. (Eds.) *Forest Biodiversity Research, Monitoring and Modelling: Conceptual Background and Old World Case Studies.* Parthenon Publishing, Paris.
Maschinski, J. and Haskins, K.E. 2012. *Plant Reintroduction in a Changing Climate: Promises and Perils. The Science and Practice of Ecological Restoration*. Island Press, Center for Resource Economics, Washington, D.C.
Maton, K.I. 2008. Empowering community settings: agents of individual development, community betterment, and positive social change. *American Journal of Community Psychology* 41: 4–21.
McComb, B., Zuckerberg, B., Vesely, D. and Jordan, C. 2010. *Monitoring Animal Populations and Their Habitats. A Practitioners's Guide.* CRC Press, Taylor and Francis, Boca Raton, Florida.
Merkel, F.R. 2010. Evidence of recent population recovery in common eiders breeding in Western Greenland. *Journal of Wildlife Management* 74: 1869–1874.

Mertz, O., Müller, D., Sikor, T., Hett, C., Heinimann, A., Castella, J.-C., Lestrelin, G. et al. 2012. The forgotten D: challenges of addressing forest degradation in complex mosaic landscapes under REDD+, *Geografisk Tidsskrift-Danish Journal of Geography* 112: 63–76.
Milner-Gulland, E.J. 2011. Integrating fisheries approaches and household utility models for improved resource management. *Proceedings of the National Academy of Sciences USA* 108: 1741–1746.
Milner-Gulland, E.J. and Rowcliffe, J.M. 2007. *Conservation and Sustainable Use: A Handbook of Techniques.* Oxford Univ. Press, Oxford, UK.
Mitchard, E.T.A., Feldpausch, T.R., Brienen, R.J.W., Lopez-Gonzalez, G., Monteagudo, A., Baker, T.R., Lewis, S.L. et al. 2014. Markedly divergent estimates of Amazon forest carbon density from ground plots and satellites. *Global Ecology and Biogeography* Doi: 10.1111/geb.12168.
Mueller, J.G., Assanou, I.H.B., Guimbo, I.D. and Almedom, A.M. 2010. Evaluating rapid participatory rural appraisal as an assessment of ethnoecological knowledge and local biodiversity patterns. *Conservation Biology* 24: 140–150.
Nadasdy, P. 1999. The politics of TEK: power and the "integration" of knowledge. *Arctic Anthropology* 36: 1–18.
Nelson, A. and Chomitz, K. 2011. Effectiveness of strict vs. multiple use protected areas in reducing tropical forest fires: A global analysis using matching methods. *PLoS ONE* 6(8): e22722. doi:10.1371/journal.pone.0022722.
Nielsen, M.R. and Lund, J.F. 2012. Seeing white elephants? The production and communication of information in a locally-based monitoring system in Tanzania. *Conservation and Society* 10: 1–14.
Nobel Peace Prize Forum 2014. *Crowd Sourcing to Create Common Ground*. Augsburg, Minneapolis. Available at http://www.youtube.com/watch?v=yEKByfh7GW0 (visited August 5, 2014).
Noss, R.F. 1990. Indicators for monitoring biodiversity: A hierarchical approach. *Conservation Biology* 4: 355–364.
Nuttall, M. (Ed.). 2005. Hunting, herding, fishing, and gathering: Indigenous peoples and renewable resource use in the Arctic. Pp. 649–690 in *ACIA, Arctic Climate Impact Assessment*. Cambridge Univ. Press, New York.
Nuttall, M. 2009. Living in a World of Movement: Human Resilience to Environmental Instability in Greenland. Pp. 292-326 in (S.A. Crate and M. Nuttall, Eds.) *Anthropology and Climate Change: From Encounters to Actions*. Left Coast Press, Walnut Creek, California.
O'Donnell, K.P., Pajaro, M.G. and Vincent, A.C.J. 2010. Improving conservation and fishery assessments with local knowledge: Future directions. *Animal Conservation* 13: 539–540.
Ohmagari, K. and Berkes, F. 1997. Transmission of indigenous knowledge and bush skills among the Western James Bay Cree women of subarctic Canada. *Human Ecology* 25: 197–222.
Organ, D.W. 1988. *Organizational Citizenship Behavior: The Good Soldier Syndrome.* Lexington Books, Lexington, Massachusetts.
Oskal, A., Turi, J.M., Mathiesen, S.D. and Burgess, P. 2009. *EALÁT. Reindeer Herders Voice: Reindeer Herding, Traditional Knowledge and Adaptation to Climate Change and Loss of Grazing Lands.* International Centre for Reindeer Husbandry, Kautokeino/ Guovdageadnu, Norway.
Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L. et al. (Eds.). 2003. *Good practice guidance for land use, land-use change and forestry.* IPCC National Greenhouse Gas Inventories Programme, Kanagawa, Japan. Available at http://www.ipccnggip.iges.or.jp/public/gpglulucf/gpglulucf_contents (visited June 4, 2014).
Penrose, D. and Call, S.M. 1995. Volunteer monitoring of benthic macroinvertebrates: Regulatory biologists' perspectives. *Journal of the North American Benthological Society* 14: 203–209.
Perrings, C., Duraiappah, A., Larigauderie, A. and Mooney, H. 2011. The biodiversity and ecosystem services science-policy interface. *Science* 331: 1139–1140.
Persha, L., Agrawal, A. and Chhatre, A. 2011. Social and ecological synergy: local rulemaking, forest livelihoods, and biodiversity conservation. *Science* 331: 1606–1608.
Peters-Guarin, G. and McCall, M.K. 2011. Participatory mapping and monitoring of forest carbon services using freeware: Cyber Tracker and Google Earth. Pp. 94–104 in (M. Skutsch, Ed.) *Community Forest Monitoring for the Carbon Market.* Earthscan, London.
Pierce, J.L. and Jussila, I. 2011. *Psychological ownership and the organizational context. Theory, research evidence, and application.* New Horizons in Management. Edward Elgar Publ., Gloucester, UK.
Pierce, J.L., Kostova, T. and Dirks, K.T. 2001. Toward a theory of psychological ownership in organizations. *Academy of Management Review* 26: 298–310.
Pierce, J.L., Kostova, T. and Dirks, K.T. 2003. The state of psychological ownership: integrating and extending a century of research. *Review of General Psychology* 7: 84–107.
Post, E., Forchhammer, M.C., Bret-Harte, M.S., Callaghan, T.V., Christensen, T.R., Elberling, B., Fox, A.D. et al. 2009, Ecological dynamics across the Arctic associated with recent climate change. *Science* 325: 1355–1358.
Pratihast, A.K. and Herold, M. 2011. *Community based monitoring and potential links with national REDD+ MRV.* Input paper no. 1 for the Forest Carbon Partnership Facility workshop ¨Linking community monitoring with national MRV for REDD+¨, 12-14 September 2011, México City. Universidad Nacional Autónoma de México, México.

Pulsifer, P.L., Huntington, H.P. and Pecl, G.T. 2014. Introduction: local and traditional knowledge and data management in the Arctic. *Polar Geography* 37: 1–4.
Pulsifer, P.L., Laidler, G.J., Taylor, D.R.F. and Hayes, A. 2011. Towards an indigenist data management program: Reflections on experiences developing an atlas of sea ice knowledge and use. *The Canadian Geographer* 55: 108–124.
Reid, R.S., Nkedianye, D., Said, M.Y., Kaelo, D., Neselle, M., Makui, O., Onetu, L. et al. 2009. Evolution of models to support community and policy action with science: Balancing pastoral livelihoods and wildlife conservation in savannas of East Africa. *Proceedings of the National Academy of Sciences USA.* doi:10.1073/pnas.0900313106.
van Rijsoort, J. and Jinfeng, Z. 2005. Participatory resource monitoring as a means for promoting social change in Yunnan, China. *Biodiversity and Conservation* 14: 2543–2573.
Rodríguez, J.P. 2003. Challenges and opportunities for surveying and monitoring tropical biodiversity – a response to Danielsen et al. *Oryx* 37: 411.
Root, T.L. and Alpert, P. 1994. Volunteers and the NBS. *Science* 263: 1205.
Royal Society 2003. *Measuring Biodiversity for Conservation.* Policy Document 11/3. The Royal Society, London.
Rudmin, F.W. and Berry, J.W. 1987. Semantics of ownership: a free-recall study of property. *The Psychological Record* 37: 257–268.
Saberwal, V.K. and Kothari, A. 1996. The human dimension in conservation biology curricula in developing countries. *Conservation Biology* 10: 1328–1331.
Sartre, J.P. 1943/1969. *Being and Nothingness: A Phenomenological Essay on Ontology*. Philosophical Library, New York.
Sejersen, F. 2003. Greenlands Nature Management (in Danish). *Grønlands Naturforvaltning*. Akademisk Forlag, Copenhagen, Denmark.
Seligman, M.E.P. 1975. *Helplessness*. Freeman, San Francisco.
Sheil, D. 2001. Conservation and biodiversity monitoring in the tropics: realities, priorities and distractions. *Conservation Biology* 15: 1179–1182.
Sheil, D. and Lawrence, A. 2004. Tropical biologists, local people and conservation: new opportunities for collaboration. *Trends in Ecology and Evolution* 19: 634–638.
Shephard, G.H., Yu, D.W., Lizarralde, M. and Italiano, M. 2001. Rain forest habitat classification among the Matsigenka of the Peruvian Amazon. *Journal of Ethnobiology* 21: 1–38.
Shirk, J.L., Ballard, H.L., Wilderman, C.C., Phillips, T., Wiggins, A., Jordan, R., McCallie, E. et al. 2012. Public participation in scientific research: a framework for deliberate design. *Ecology and Society* 17(2): 29.
Sikor, T. (Ed.). 2013. *The Justices and Injustices of Ecosystem Services*. Routledge, London.
Singh, N.J. and Milner-Gulland, E.J. 2011. Monitoring ungulates in Central Asia: current constraints and future potential. *Oryx* 45: 38–49.
Skutsch, M. (Ed.). 2011. *Community Forest Monitoring for the Carbon Market*. Earthscan, London.
Sodhi, N.S. and Ehrlich, P.R. (Eds.). 2010. *Conservation Biology for All*. Oxford Univ. Press.
Sommerville, M.M., Milner-Gulland, E.J. and Jones, J.P.G. 2011. The challenge of monitoring biodiversity in payment for environmental service interventions. *Biological Conservation* 144: 2832–2841.
Speer, P.W. and Hughey, J. 1995. Community organizing: an ecological route to empowerment and power. *American Journal of Community Psychology* 23: 729–748.
Spellerberg, I.F. 2005. *Monitoring Ecological Change.* Cambridge Univ. Press, Cambridge, UK.
Spiegelhalter, D.J. 2014. The future lies in uncertainty. *Science* 345: 264.
Staddon, S.C., Nightingale, A. and Shrestha, S.K. 2012. Who and what is participatory ecological monitoring for. Pp. 164–170 in (S.C. Staddon, Ed.) *Keeping track of nature: interdisciplinary insights for participatory ecological monitoring.* The University of Edinburgh, Edinburgh.
Staddon, S.C., Nightingale, A. and Shrestha, S.K. 2014. The social nature of participatory ecological monitoring. *Society & Natural Resources* 27: 899–914.
Stephenson, J. and Moller, H. 2009. Cross-cultural environmental research and management: challenges and progress. *Journal of the Royal Society of New Zealand* 39: 139–149.
Sullivan, B.L., Aycrigg, J.L., Barry, J.H., Bonney, R.E., Bruns, N., Cooper, C.B., Damoulas, T. et al. 2014. The eBird enterprise: An integrated approach to development and application of citizen science. *Biological Conservation* 169: 31–40.
Sutherland, W.J., Gardner, T.A, Haider, L.J. and Dicks, L.V. 2014. How can local and traditional knowledge be effectively incorporated into international assessments? *Oryx* 48: 1–2.
Sutherland, W.J., Pullin, A.S., Dolman, P.M. and Knight, T.M. 2004. The need for evidence-based conservation. *Trends in Ecology and Evolution* 19: 305–308.
Tengö, M., Brondizio, E., Elmqvist, T., Malmer, P. and Spierenburg, M. 2014. Connecting diverse knowledge systems for enhanced ecosystem governance – the multiple evidence base approach. *Ambio* 43: 579–591.

Terborgh, J. and Davenport, L. 2002. Monitoring Protected Areas. Pp. 395–408 in (J. Terborgh, C. van Schaik, L. Davenport and M. Rao, Eds.) *Making Parks Work, Strategies for Preserving Tropical Nature*. Island Press, Washington, D.C.

Thompson, W.L., White, G.C. and Gowan, C. 1998. *Monitoring Vertebrate Populations*. Academic Press, San Diego.

Tidball, K.G. and Krasny, M. 2012. A role for citizen science in disaster and conflict recovery and resilience. Pp. 226–233 in (J.L. Dickinson and R. Bonney, Eds.) *Citizen Science*. Cornell Press, Ithaca, New York.

Topp-Jørgensen, E., Poulsen, M.K., Lund, J.F. and Massao, J.F. 2005. Community-based monitoring of natural resource use and forest quality in montane forests and miombo woodlands of Tanzania. *Biodiversity and Conservation* 14: 2653–2677.

Townsend W.R., Borman A.R., Yiyoguaje E. and Mendua L. 2005. Cofán Indians' monitoring of freshwater turtles in Zábalo, Ecuador. *Biodiversity and Conservation* 14: 2743–2755.

Turnhout, E., Bloomfield, B., Hulme, M., Vogel, J. and Wynne, B. 2012. Listen to the voices of experience. *Nature* 488: 454–455.

United Nations 2008. *Declaration on the Rights of Indigenous Peoples.* United Nations.

United Nations 2009. *State of the World's Indigenous Peoples.* United Nations Department of Economic and Social Affairs, Division for Social Policy and Development, Secretariat of the Permanent Forum on Indigenous Issues ST/ESA/328. Available at www.un.org/esa/socdev/unpfii/documents/SOWIP web.pdf (visited January 15, 2014).

United Nations Environment Programme 2010. *GEO5*. UNEP, Nairobi.

United Nations Environment Programme 2011. *Report of an international science workshop on assessments for an intergovernmental science-policy platform on biodiversity and ecosystem services, held in Tokyo from 25 to 29 July 2011*. UNEP/IPBES.MI/1/INF/12. Available at http://ipbes.net/resources/previous-ipbes-meetings/first-session-of-plenary.html (visited February 4, 2014).

United Nations Environment Programme 2012a. *Report of the second session of the plenary meeting to determine modalities and institutional arrangements for an intergovernmental science-policy interface on biodiversity and ecosystem services.* UNEP/IPBES.MI/2/9. Available at http://ipbes.net/resources/previous-ipbes-meetings/second-session-of-plenary.html (visited June 4, 2014).

United Nations Environment Programme 2012b. *Consideration of initial elements: recognizing indigenous and local knowledge and building synergies with science.* IPBES/1/INF/5. Available at http://www.ipbes.net/plenary/ipbes-1.html (visited February 4, 2014).

United Nations Environment Programme 2013. *Indicators relevant for traditional knowledge and customary sustainable use.* UNEP/CBD/WG8J/8/9. Available at https://www.cbd.int/doc/?meeting=WG8J-08 (visited January 15, 2014).

United Nations Framework Convention on Climate Change 2012. *Report of the Conference of the Parties on its Seventeenth Session, Held in Durban from 28 November to 11 December 2011*. Report no. FCCC/CP/2011/9. UNFCCC, Bonn. Available at http://unfccc.int/resource/docs/2011/cop17/eng/09.pdf (visited August 4, 2014).

Wals, A.E.J., Brody, M., Dillon, J. and Stevenson, R.B. 2014. Convergence between science and environmental education. *Science* 344: 583.

Wangwacharakul, V., Claridge, G. and Mather, R. 1996. *Biodiversity Monitoring and Evaluation in the Lao PDR: Developing a Protected Area Approach*. MIDAS Agronomics Co. Ltd., Bangkok.

Walters, C.J. and Hilborn, R. 1978. Ecological optimisation and adaptive management. *Annual Review of Ecology, Evolution, and Systematics* 9: 157–188.

Weatherhead, E., Gearheard, S. and Barry, R.G. 2010. Changes in weather persistence: Insight from Inuit knowledge. *Global Environmental Change* 20: 523–528.

Wilson, D.E., Cole, F.R., Nichols, J.D., Rudran, R. and Foster, M.S. (Eds.). 1996. *Measuring and Monitoring Biological Diversity. Standard Methods for Mammals.* Smithsonian Institution Press, Washington and London.

Word Fish Center 2008. *Global Coral Reef Monitoring Network*. Available at http://www.gcrmn.org (visited June 15, 2014).

World Bank 1992. *Guidelines for Monitoring and Evaluation of GEF Biodiversity Projects.* The World Bank, Washington, D.C.

World Bank 1998. *Guidelines for Monitoring and Evaluation for Biodiversity Projects.* Environment Department Note No. 65. The World Bank, Washington, D.C.

World Bank 2010. *World Development Report 2010. Development and Climate Change*. Available at http://www.worldbank.org/wdr (visited August 5, 2014).

WWF 2012. *Living Planet Report*. WWF International, Gland, Switzerland.

Vincent, A.C.J. and Harris, J.M. 2014. Boundless no more. *Science* 346: 420–421.

Yoccoz, N.G., Nichols, J.D. and Boulinier, T. 2001. Monitoring of biological diversity in space and time. *Trends in Ecology and Evolution* 16: 446–453.

Yoccoz, N.G., Nichols, J.D. and Boulinier, T. 2003. Monitoring of biological diversity – a response to Danielsen et al. *Oryx* 37: 410.

Appendices I-XXII: Included Publications

APPENDIX I

Danielsen, F., Balete, D.S., Poulsen, M.K., Enghoff, M., Nozawa, C.M. and Jensen, A.E. 2000.
A simple system for monitoring biodiversity in protected areas of a developing country.
Biodiversity and Conservation 9: 1671–1705.

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Biodiversity and Conservation **9**: 1671–1705, 2000.
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A simple system for monitoring biodiversity in protected areas of a developing country

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Received 29 April 1999; accepted in revised form 21 February 2000

Abstract. The achievements of initiatives to strengthen biodiversity conservation in developing countries may be difficult to assess, since most countries have no system for monitoring biodiversity. This paper describes a simple and cost-effective, field-based biodiversity monitoring system developed specifically for areas where 'specialist staff' is lacking. We discuss the preliminary lessons learned from protected areas in the Philippines. Whilst the monitoring system aims to identify trends in biodiversity and its uses so as to guide management action, it also promotes the participation of local people in the management, stimulates discussions about conservation amongst stakeholders and builds the capacity of park staff and communities in management skills. In addition, it seeks to provide people with direction regarding the aims of protected areas, and reinforces the consolidation of existing livelihoods through strengthening community-based resource management systems. The field methods are: (1) standardised recording of routine observations, (2) fixed point photographing, (3) line transect survey, and (4) focus group discussion. Both bio-physical and socio-economic data are used and given equal importance. The system can be sustained using locally available resources. The approach is useful in countries embarking on shared management of park resources with local communities, where rural people depend on use of natural ecosystems, and where the economic resources for park management are limited. We hope this paper will encourage other countries to develop their own biodiversity monitoring system, letting its development become a means for capacity building whilst at the same time supporting the creation of ownership.

Key words: biodiversity, developing country, monitoring, participation, protected area

Introduction

Attempts to curb degradation of natural ecosystems world-wide have increasingly focused on the establishment of protected areas (e.g. Groombridge 1992), and these now cover 6.4% of the world's land area (WRI et al. 1998). The achievements of protected area management may be difficult to assess, since in most developing countries there is at present no established system for monitoring trends in biodiversity.

Countries contracting to the Convention on Biological Diversity are obliged to monitor biodiversity (Article 7.b), and donor countries increasingly demand account-

ability and quantifiable achievements in return for their assistance. The development of biodiversity monitoring systems now attracts a significant proportion of the international funding for biodiversity conservation. The Global Environment Facility, for example presently the single largest funding source for biodiversity conservation in developing countries (Wells 1998) – requires the majority of the conservation projects it finances to include biodiversity monitoring, although what this means in practice remains to be seen.

The Protected Area and Wildlife Bureau (PAWB) of the Department of Environment and Natural Resources (DENR) in the Philippines takes part in such international efforts (DENR and UNEP 1997; PAWB-DENR 1998) and, in addition, has legal requirements for monitoring stipulated in the NIPAS Act (DENR 1992).

Basic assumptions for quantitative recording of biodiversity have been described in the literature (e.g., Bibby et al. 1992; Wilson et al. 1996; Dallmeier and Comiskey 1998; Margules et al. 1998; Thompson et al. 1998). The broader concepts of biodiversity monitoring have also been outlined (e.g., Noss 1990; Brown and Wyckoff-Baird 1992; World Bank 1992; Harmon 1994; Kremen et al. 1994; Wangwacharakul et al. 1996). However, few suggestions have been made as to how these may be meaningfully translated into a developing country context (e.g., Fuller 1998; Kremen et al. 1998; Margoluis and Salafsky 1998; World Bank 1998; Hellier et al. 1999), given the inherent tensions between standardisation of data, facility of collection and ease of analysis (IBAMA 1998). Initial efforts have tended to follow the standards used in developed countries, probably because Western assistance has been involved. Compared with the West, developing countries have very limited human capacity and financial resources available. Furthermore, most protected areas in developing countries serve to meet the daily subsistence requirements of millions of rural poor (see e.g. Saberwal and Kothari 1996). It is therefore unlikely that Western-monitoring systems are suited to developing countries.

Most monitoring systems in tropical forests include the establishment of permanent vegetation plots where all plants above a certain size are identified to species and measured, for instance every 5 years. Such monitoring can generate data for rigorous hypothesis testing and provide important scientific evidence. However, since the frequency of data collection is low and limited data is collected on the use of resources, such exercise rarely provides any input to management. For conservation purposes protected areas in developing countries need monitoring that is realistic and at the same time useful for guidance rather than what is ideally required for in depth studies of how community structure and species richness are affected by different environmental changes.

In this paper we describe and discuss a simple and cost-effective biodiversity monitoring system for protected areas, which:

1. requires a minimum of training and education on the part of park staff,
2. requires little equipment and financial resources,
3. seeks to encourage participation of local communities in park management, and

4. strengthens existing local systems for monitoring and managing natural resources.

The ability of this monitoring system to detect trends in abundance of species and resource uses (i.e. to distinguish a situation different from the null hypothesis) could be strengthened by using more standardised methods e.g. territory mapping of birds (Bibby et al. 1992), arthropod protocols (Coddington et al. 1991) and permanent forest inventory plots (Alder and Synnott 1992). However, while more standardised methods can be valuable tools, their usefulness will in practice be constrained by:

1. the shortage of trained field scientists, support staff, and facilities,
2. the small proportion of taxa described and sufficiently known to make them useful in applied programs, and
3. the lack of identification manuals for most tropical species groups.

The aim of this monitoring system is to ensure better management and the involvement of local people rather than data-based falsification of scientific hypotheses concerning variation in biodiversity values. By allowing park staff to carry out the field assessments, this monitoring encourages them into the field and improves their capacity for park management.

The monitoring system was developed for use in protected areas of the Philippines. It was designed and tested in three protected areas and the Government is now embarking on large-scale implementation of the system in all the country's protected areas (G. Caleda *in litt*. 1998). We hope this paper will help and encourage others to proceed with similar efforts elsewhere.

We define 'monitoring' as data sampling which is repeated at certain intervals of time for management purposes. We distinguish this from surveys by emphasising repeated and replicable measurements over an extended time frame and by focusing on rates and magnitudes of change (modified from the World Bank 1992).

In developing countries in particular, most protected area management decisions are taken at a local level (e.g. Groombridge and Jenkins 1996), and the system thus focuses on monitoring at the level of the single protected area (or management unit).

Methods

Development of this monitoring system was carried out over a 3-year period, from 1996 to 1998, alongside building capacity among protected area staff and local decision-makers in protected area management, undertaking inventories of the biodiversity and its use, providing management information input, and raising awareness about conservation amongst local communities and decision-makers in three protected areas. Our team comprised Filipino professionals with expertise in ecology, field biology, socio-economy and training, a Danish ecologist and a Danish rural sociologist. The Filipino staff input, in terms of person-months, was 5–6 times as

high as the external staff input. The team was trained in protected area management and integrating conservation with local development.

We searched the literature for monitoring techniques based on conventional methods and then studied current natural resource and protected area management practices at field level in the three protected areas. Protected area staff and non-governmental organisations working with community development in the areas participated in the surveys. Survey findings were subject to interdisciplinary discussions within the survey team in the field or immediately after the surveys; this was time-consuming but generated awareness about methodological problems that had to be solved. It also meant that the conclusions were acceptable to a broader range of people and it encouraged ownership of the monitoring system. Survey findings were brought back to the communities and protected area field staff in order to validate results and involve local stakeholders in the process. The survey helped us identify priority species, resource uses and management interventions, and to adapt the monitoring system to the real situation in the field.

Based on the literature and the field survey, a theoretical framework for monitoring biodiversity was drafted and discussed at a national workshop (University of the Philippines, Los Baños, April 1997; Pollisco et al. 1997). This was attended by managers and scientists from the Philippines and abroad. We tested possible field methods, discussed them with field staff, developed a training package and identification guides for priority species and carried out one-week training courses for protected area staff in the forest and in the protected area villages where the staff would be working. Field methods and data interpretation were discussed in a workshop with senior staff of the Protected Areas and Wildlife Bureau of DENR (May 1998), and a manual was prepared (Nordeco and DENR 1998a). Regular visits were subsequently made to the sites to assist and supervise park staff in field implementation.

Study areas

The monitoring system was developed on the basis of fieldwork in three Natural Parks: Northern Sierra Madre, Bataan, and Mt. Kitanglad Range (Figure 1). These are covered by the Conservation of Priority Protected Areas Project (CPPAP), which supports the construction of park infrastructure, development of management plans, mapping, boundary delineation and demarcation, advocacy, community consultation and training, and non-degrading livelihood projects in buffer and multiple use zones.

Northern Sierra Madre Natural Park is in Isabela Province, north-eastern Luzon. With 359,486 ha, it is the largest protected area in the country. It has 36 park staff. The Park comprises the largest area of lowland forest remaining in the Philippines and is one of the few areas with a natural transition between coastal and terrestrial ecosystems. The Sierra Madre mountain range is the main water catchment area in eastern Luzon, which is one of the country's most important rice-producing areas.

During the El Niño of 1997, the Sierra Madre was the only part of the country that did not suffer from water supply deficit. A total of 70 wildlife species regarded as globally threatened or near-threatened by IUCN (1996) are known within the Park,

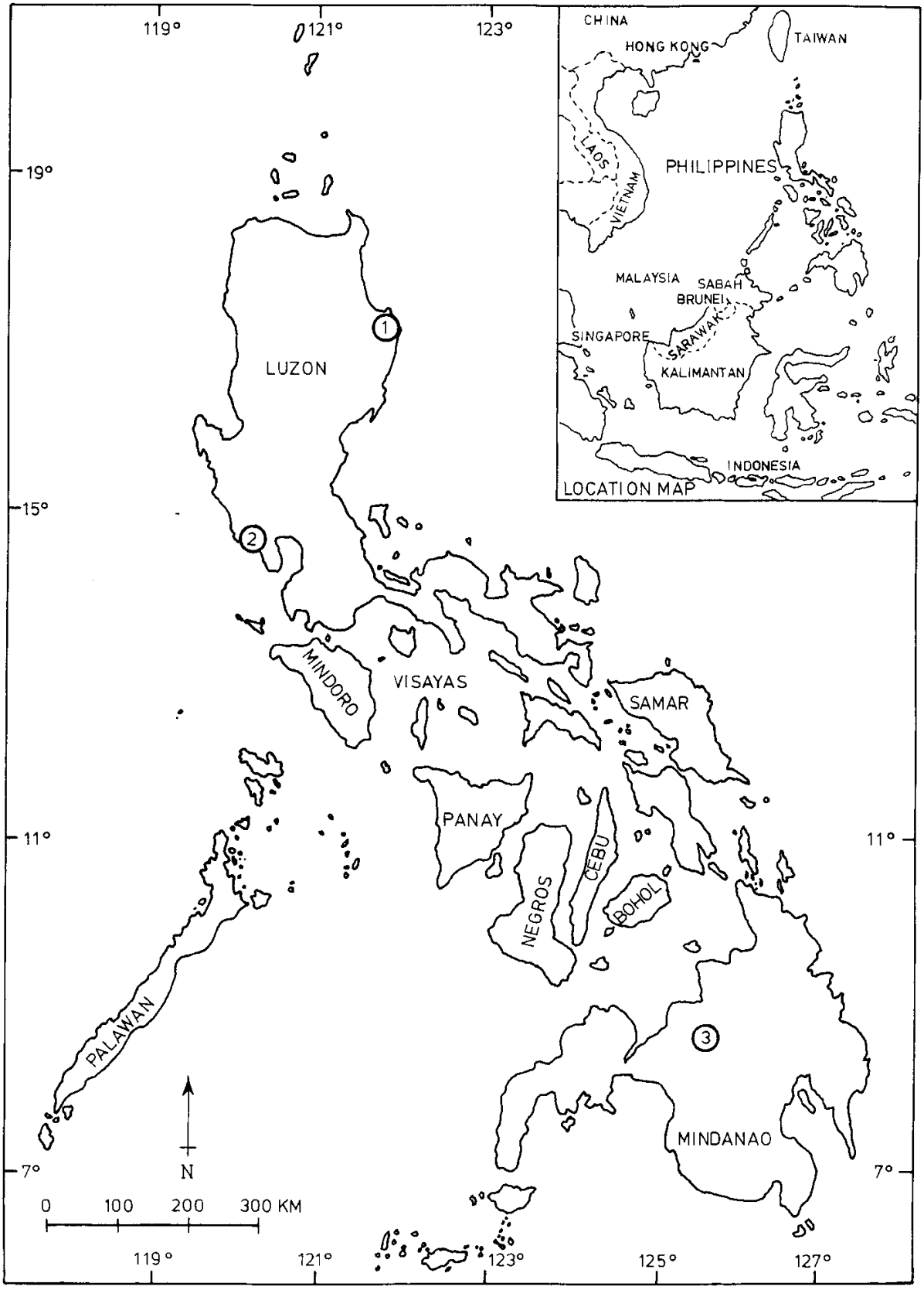

Figure 1. Location of Northern Sierra Madre Natural Park (1), Bataan Natural Park (2), and Mt. Kitanglad Range Natural Park (3) in the Philippines.

including the Golden-crowned Flying Fox *Acerodon jubatus*, Dugong *Dugong dugon*, Philippine Eagle *Pithecophaga jefferyi* and Estuarine Crocodile *Crocodylus porosus*. A total of 1000 indigenous Agtas and 31,500 migrants residing adjacent to or within the Park heavily depend on the forest and coastal resources. The human activities with most negative impact on the conservation values of the Park are logging (both large and small-scale), swiddening, agricultural development, and forest clearing for land speculation (Nordeco and DENR 1998b).

Bataan Natural Park is located in Bataan Province in western Luzon. It covers 23,668 ha and has 30 park staff. A total of 25 wildlife species regarded as globally threatened or near-threatened by IUCN (1996) are known within the park. A total of 300 indigenous people and 3000 migrants reside in the Park. The indigenous people depend on the forest as a source of food and medicine, whilst other residents largely use the forest for cultivation, extraction of bamboo and timber, and fishing. Human activities severely impacting on the Park are: construction of roads, buildings and factories, and large-scale plantations of coffee, mangoes and other tree crops (Nordeco and DENR 1998c).

Mt. Kitanglad Range Natural Park is located in Bukidnon Province in northern Mindanao. It covers 40,176 ha and has 24 park staff. The Park protects the major part of the remaining forest in the Province and comprises one of the largest areas of montane forest in the country. It is one of the main water catchment areas in northern Mindanao. A total of 45 wildlife species regarded as globally threatened or near-threatened by IUCN (1996) have been recorded in the Park, including the Philippine Eagle *Pithecophaga jefferyi* and a mammal only known in this area, the Mindanao Pygmy Fruit Bat *Alionycteris paucidentata*. A total of 34,000 indigenous people and 9000 migrants reside in or adjacent to the Park. The indigenous people and households close to the forest heavily depend on the forest as a source of food and medicine. They use more than 500 species of flora and fauna. The human activities with the most severe impact on the Park are the establishment of commercial crop plantations and large farms, swiddening and small-scale logging (Nordeco and DENR 1998d).

Theoretical framework for monitoring biodiversity in Philippine protected areas

Questions the monitoring is intended to answer

The ultimate objective of the Philippine protected areas is “to secure for the Filipino people [..] the perpetual existence of all native plants and animals” (NIPAS Act; DENR 1992). Guided by this long-term objective, monitoring is intended to answer the following questions in each protected area:

- Are habitats and ecosystems being degraded?
- Are the populations of threatened species of plants and animals declining?

- What are the causes?
- Has management intervention had the intended impact on the ecosystem?
- Are there increased benefits to local people from sustainable natural resource use?

In other words, monitoring should answer the question: are the management interventions in the area effective in addressing biodiversity conservation?

Existing monitoring activities

Many protected area communities in the Philippines, especially indigenous people, still implement some form of traditional system for controlling access to resources. These people have lived in a particular area for generations and have intimate knowledge of the habitats and behaviour of wildlife species. Observing events in nature influences their survival strategies and resource use. Traditional systems for controlling access to resources are used in all three Natural Parks concerned. Community leaders and people regularly discuss the availability and quality of natural resources. One such example is the Talaandigs and Higaonon in Mt. Kitanglad Range Natural Park who perform rituals for hunting and forbid resource extraction in some places which are called *lalaw* (Nordeco and DENR 1998d). In this way, they control and monitor access to certain areas and the use of resources. Merely by living in the areas, using the resources and observing their environment, they monitor changes in the resources. The biodiversity monitoring system was designed to build upon and strengthen existing community-based monitoring.

The central Department of Environment and Natural Resources (DENR) regularly monitors forest cover, trade in endangered species, etc., but most of this data compilation is undertaken on a country-wide or regional basis, and is therefore of limited use for local protected area management. Further monitoring activity is undertaken by local DENR staff who regularly visit the field where, for example, they assess the size of extracted timber.

Available human capacity and financial resources

The availability of human capacity and financial resources has an important bearing on a monitoring system. In each protected area covered by the Conservation of Priority Protected Areas Project (CPPAP), the following people typically work with protected area management: staff of the Protected Area Superintendent (PASu) 8–10 people, staff of the Host NGO (HNGO) 8–15 people and local forest guards up to ca. 25 people. The forest guards can be '*Datu*'s or other members of the indigenous communities, and they may be selected by the local people. There is a high turnover among PASu staff (personal observation). In some protected areas, each PASu employee is responsible for one particular geographical area, for instance two to four valleys.

On the CPPAP sites, the PASu staff have B.Sc.'s in forestry or an associated field, and they receive training in different aspects of protected area management. Since in the past, protected area management activities have mainly focused on enforcing regulations, there is limited capacity for creating a dialogue with local communities. Local people perceive PASu staff as law enforcers and they are sometimes unwilling to share information.

One HNGO employee is assigned to the same area such that in any one part of the protected area one PASu and one HNGO are responsible for Government and NGO activities respectively. The HNGO staff generally have a background in community organising or forestry. While most of the local forest guards have no formal education, some have attended primary or even secondary school. They have not received any systematic training in protected area management. Given the size of most protected areas and the high number of people living there, the workload for the protected area staff is enormous. They have very limited time available for monitoring work, and this is not likely to change.

The financial resources available for monitoring are limited. For CPPAP sites, there are some funds set aside for this purpose but beyond that project the only funding sources are the endowment fund for each protected area (the Integrated Protected Area Fund, IPAF), and the Government of the Philippines. The local IPAF is expected to provide funds for alternative livelihood activities in the buffer zone, whilst it is hoped that the Government will continue to fund basic protected area staffing and transport costs etc. Biodiversity monitoring has to 'compete' for funds with other highly needed activities.

For a monitoring system to be sustained it needs to be based on locally available personnel and resources. Satellite imagery, aerial surveillance and in-depth sociological and biological inventories can generate very useful data for protected area management. These methods, however, rely on personnel and equipment, such as computer technology, which is not available at the level of the local protected area. Given the limited availability of funding for biodiversity, it was thus important to choose simple monitoring procedures. The monitoring nevertheless had to be able to provide tangible results that could be used – even in the short-term – for improving protected area management. Otherwise protected area staff would not be likely to continue the data compilation.

Management levels in protected areas

Given the constraints in the human capacity and financial resources available for protected area management, we envisaged that the management level in most protected areas would remain rather limited: only the most important management interventions would be undertaken. The biodiversity monitoring system was designed to focus on addressing priority issues and providing input to protected area manage-

ment that would be of a sufficiently general nature to lead to actions which could be implemented.

Indicators

An 'indicator for biodiversity' can be defined as a parameter which describes the state of biodiversity in an area. Indicators serve three main functions: (1) they measure complex phenomena, but (2) in a simplified way, by reducing the numbers of measurements normally required to make an exact presentation of a situation, (3) thereby promoting communication about complex relationships (Hammond et al. 1995).

Biodiversity indicators for protected areas should ideally highlight, as unambiguously as possible, emerging problems in biodiversity conservation and draw attention to the effectiveness of management policies and actions (Hammond et al. 1995; a review of indicators for ecosystem health is provided by Vora 1997). Relevant criteria regarding the usefulness and practicality of indicators for biodiversity in Philippine protected areas are (modified from Noss 1990; Weber 1990; Wangwacharakul et al. 1996) those which:

- are easy and cost-effective to collect, analyse and report;
- are meaningful to local people;
- point as directly as possible to changes in biodiversity and resource use;
- are suited for providing a continuous assessment over a wide range of stress;
- are able to differentiate between natural cycles or trends (weather, climate, etc.) and those induced by anthropogenic stress;
- are relatively independent of sample size;
- are sufficiently sensitive to provide an early warning of change;
- are applicable over the range of ecosystems in the Philippines.

Since no single indicator possessed all of these desirable properties, a (small) set of complementary indicators was required.

We found it most relevant to concentrate on indicators at ecosystem/habitat/community level, at species/population level, and at what we called 'use of ecosystem/species' level. Based on workshop discussions, we selected four indicators:

1. Changes in number of sightings of designated species and local resource uses;
2. Changes in size of vegetation type blocks and in land-use of priority areas;
3. Changes in frequency of detection of specified signs of presence of designated fauna species and local resource uses along established transects;
4. Changes in perceived harvest volume per effort and in number of people engaged in specific biodiversity impacting activities within a given time period.

For each of these indicators, we assessed possible use for management decisions, habitat coverage, proposed field method, type of data set, proposed compilers, equipment needs, frequency of data collection, data storage, and general pros and cons (Table 1). The indicators were intended to focus on trends (or changes in status) in biodiversity and resources rather than changes in absolute figures.

Approach and methods

The objective of the Philippine biodiversity monitoring system is to improve the information available for decision-makers in protected areas through the regular collecting of data on natural biological resources and their utilization. The focus is on identifying trends in important biodiversity assets of an area and the use of the area's biodiversity in order to guide action in park management. In addition, the system is intended to improve the participation of protected area communities in park management.

Who undertakes biodiversity monitoring?

The monitoring system is for use by protected area staff, local forest guards, local environmental groups and others from the local communities. It is designed so that anyone interested in gathering information on changes in the environment can use it. Since people living in or adjacent to protected areas represent important sources of information it is an advantage when the protected area staff responsible for biodiversity monitoring are different to those involved in enforcement in order to encourage open discussion with local people.

How are the data used?

The information gathered is analysed by the Head of the Protected Area Office. The results are used by the Protected Area Management Board to take better decisions on the management of the land and people in the protected areas. Sometimes the information alerts the Head of the Protected Area Office to situations which should be examined further. The information is also used by the people living in or adjacent to the protected area to improve local resource management.

Which species and resource uses are monitored?

During the development of the monitoring system it was on several occasions suggested that all plant and animal species living within the protected areas should be monitored or that some indicator groups would be used which would represent the total biodiversity well. Biodiversity in a Philippine protected area encompasses thousands of life-forms, many of them not even named and described. It would be impossible to monitor all of these and there is no *a priori* way of assessing how specific well-known groups such as birds or larger mammals will reflect the total biodiversity. We do not even know what a species richness estimate will tell us as forest disturbance often leads to an increase in species richness even though forest specialists decline. The biodiversity of a Philippine park will probably remain virtually the same provided no large-scale habitat changes take place. If habitat changes do take place

Table 1. Four indicators for monitoring biodiversity and resource use in Philippine protected areas.

	Indicator 1	Indicator 2	Indicator 3	Indicator 4
Indicator	Changes in number of sightings (or 2nd hand records provided by local people) of designated species and local resource uses (species and use of ecosystem/ species level).	Changes in size of vegetation type blocks and in land-use of priority areas (ecosystem/habitat/ community and use of ecosystem/species level).	Changes in frequency of detection of specified signs of presence of designated fauna species and local resource uses along established transects for the same search effort (species/population and use of ecosystem/species level).	Changes in perceived harvest volume per effort and in number of people engaged in specific biodiversity impacting activities within a given time period (use of eco-system/species level).
Possible use	Indicates possible changes in relative abundance of species and resource use.	Indicates effectiveness of habitat protection and conservation. It can tell if the size of important habitats are declining and why.	Indicates possible changes in wildlife population size/human intensity of resource use and/or shift in range of wildlife/human resource extraction.	Provides an early warning of overharvesting situations and indicates changes in resource use, and effectiveness of park in providing benefits to local communities.
Habitat coverage	Useful in both land and water habitats.	Useful in land habitats, particularly in undulating terrain and along curved coastlines.	Useful in land habitats.	Useful in both land and water habitats.
Field method	Field Diary method. Standardised recording of routine observations on resource use and wildlife in a simple pocketbook or on a data sheet during regular patrols.	Photo Documentation method. On-the-ground fixed point photographing of selected hillsides in priority forest blocks at regular intervals.	Transect Walk method. Line-transect survey of wildlife and resource use along permanent routes.	Focus Group Discussion method. Park staff cooperate with community leaders and establish a volunteer Community Monitoring Group of 5–8 persons, who are encouraged to collect information on a regular basis between quarterly discussions with park staff. The results are analysed by the park staff and presented annually for the entire village in order to enable the communities' inputs and responses to be obtained, leading to agreed mitigating actions.

Table 1. Continued.

	Indicator 1	Indicator 2	Indicator 3	Indicator 4
Data set	Field data sheet with date, name of observer, location, species, number/amount and remarks.	Colour photo 10 × 15 cm with date, location and name of photographer.	Transect Walk data sheet with date, name of observer, location, species, number/amount and remarks.	Amount of resource harvested (per unit effort) in a defined area as recorded by a community or sub-group; Number of people engaged (total or extrapolated from a sample).
Compilers	All protected area staff. Skills needed in communicating with local people and in identifying species.	Protected area staff with a working knowledge of the basic operations of a camera.	Protected area staff with skills in identifying species. Each transect route should be surveyed by the same person.	Protected area staff who are not involved in enforcement activities. One person facilitates discussions and another records the minutes. Skills in PRA methods are an advantage.
Equipment	Notebook, pen, field guide and binoculars.	Camera with battery, compass, films, forms and, if possible, a tripod. During establishment of this method other needed equipment is a topographic map and, if possible, an altimeter, a GPS, and paint or other materials for marking the site permanently.	Binoculars, field guide, watch, Transect Walk data sheet, water container with water, and food. During establishment of this method other equipment needed is a topographic map, compass, a long string (50 or 100 m), permanent marker (paint), and, if possible, a GPS and an altimeter.	Field guide, large sheets of paper, markers, food.
Frequency	Protected area staff keep a field diary whenever they are in the field.	Protected area staff take quarterly photos. This may later be reduced to annually at view-points where no changes in land-use and habitats have occurred. Typically one protected area staff can be responsible for 3–5 photo documentation sites.	Each Transect Walk route is walked once every quarter within a defined two-week period. Typically one protected area staff can be responsible for 3–5 routes.	A discussion meeting of two hours is undertaken quarterly with the Community Monitoring Group. Once a year a meeting is held with the village. Monitoring Groups can be be set up in all settlements within the protected area. Two park staff can be responsible for 4–6 Monitoring Groups.

Data storage	If a notebook is used, it is stored carefully. If seperate sheets of paper are used, they are filed in a ring-binder and never taken to the field again.	Each photo is marked with date, location and name of photographer, and numbered according to the sequence of frames on the negative film. Negatives and prints are kept in a photo-album or ring-binder in a safe dry place	After each Transect Walk, the observations written in the Transect Walk data sheet are tallied. The filled out form is filed in a ring-binder at the Protected Area Office. A copy is submitted to the Regional DENR for safe storage.	Minutes of the meetings are stored in a ring-binder in the Protected Area Office.
Pros	This method is easy to undertake in the field.	Minimal staff training needed. Data-set is objective, independent of observer (and identification skills) and of permanent value. Photos are useful when presenting results of monitoring as most people will be convinced by photographic documentation. In addition, ground-based photos are useful for ground-truthing of remote sensing images.	Minimal staff training needed. Corrected for effort. Relatively easy interpretation.	Minimal training needs. Relatively easy interpretation. Encourages a dialogue between park staff and local communities. When the park communities are directly involved in biodiversity monitoring they will become more aware of the need for conservation and they are more likely to agree on, and participate in, law enforcement and regulation of resource use.
Cons	Limited correction of effort possible thus easily biased, for instance, by changes in patrol routines. Only very large changes in relative abundance of species or resource use can be detected.	Staff need camera operation skills. Expensive.	Staff need identification skills. Staff transfer should be minimal. Biased by seasonal changes in detectability of wildlife.	It is often unclear whether resources are harvested inside or outside of a protected area. There may be no clear entry/exit point. People may be reluctant to provide harvest information. Data is qualitative. Information is not objective.

Table 1. Continued.

	Indicator 1	Indicator 2	Indicator 3	Indicator 4
Remarks	Some effort correction possible, if data is confined to specified locations and a constant number of informants.	Careful selection of sites is critical. Sites should overlook forest in seriously threatened areas where logging, swiddening or other disturbance may occur or recently occurred. A few sites should be in areas without human use. Sites should be easily accessible (such as view-points along the patrol routes), from where one can see the surrounding landscape (not just the nearest few trees).	Careful selection of transect routes is critical. Patrolling routes which pass through primary forest can be useful. Some should pass through areas with human use, others through areas with no or minimal human use. Routes should be easily accessible. Areas which are not safe to travel in alone should be avoided.	The information is based on local communities' own perceptions of trends. However, data gathered continuously from a number of representative communities can provide a valid picture of general trends.

these will probably be the result of human activity. We therefore found it reasonable to focus biodiversity monitoring mainly on key habitats and uses in the parks.

We identified species and signs of resource uses which we thought would provide useful proxy information about the unique biodiversity of Northern Sierra Madre Natural Park, Bataan Natural Park and Mt. Kitanglad Range Natural Park (Table 2).

Some species may be more sensitive or more threatened than those we selected. None of these, however, are easily identified. Results based on surveys of species which are difficult to identify are likely to reflect the identification skills of the observer rather than a change in species abundance. Species which are recorded only

Table 2. Species and signs of resource uses which are monitored in the natural parks, Northern Sierra Madre, Bataan and Mt. Kitanglad Range.

English name	Species	Indicator for
Mammals		
Long-tailed Macaque	*Macaca fascicularis*	f, H
Philippine Warty Pig	*Sus philippensis*	f, H
Philippine Brown Deer	*Cervus mariannus*	f, H
Large flying foxes	*Acerodon jubatus/Pteropus vampyrus*	f, H
Dugong	*Dugong dugon*	s, H
Birds		
Philippine Eagle	*Pithecophaga jefferyi*	f, H
Philippine Duck	*Anas luzonica*	w, H
Philippine Scrubfowl	*Megapodius cumingii*	cfo, E
Rufous Hornbill	*Buceros hydrocorax*	f
Tarictic Hornbill	*Penelopides panini*	f
Red Junglefowl	*Gallus gallus*	f, H
Pigeons and doves[a]	Columbidae	f, H
Bleeding-heart Pigeon	*Gallicolumba luzonica/criniger*	f, H
Philippine Eagle-Owl	*Bubo philippensis*	f
Reptiles		
Crocodile	*Crocodylus mindorensis/porosus*	w, H
Marine turtles	*Chelonia mydas*	s, c, H
	Erethmochelys imbricata	s, c, H
Shellfish		
Giant Triton	*Charonia tritonis*	c, S
Scaly Giant Clam	*Tridacna squamosa*	c, S
Signs of resource uses		
Stump		L
Piece of timber		L
Bundle of rattan		R
Person (and activity)		U
Sound of chainsaw		L

[a] Experienced observers can distinguish between different pigeons and doves.
Habitats: f – forest habitat; cfo – coastal forest habitat; w – wetland habitat (fresh/brackish water); s – seagrass bed habitat; c – coral reef habitat.
Human uses: H – hunting; E – egg collecting; S – shellfish gathering; L – logging; R – rattan gathering; U – resource use.

rarely will not generate enough data. Species where the reason for possible change in status can be relatively easily established (habitat versus hunting) are preferred.

Other parks may have different priority species and resource uses for monitoring. We have recommended that protected area staff in other parks should assess whether there are other species or signs of resource uses which are equally useful and practical to monitor in their park and change the list accordingly.

Equipment

Only basic equipment is needed. These are: notebook and pencils, binoculars, watch, compass, camera with batteries and film, markers, large sheets of paper, ring binders for data storage, Photo Documentation forms, Transect Walk field data sheet, and food. Whilst setting up the monitoring system it is also useful to have an altimeter and a GPS (Global Positioning System receiver). Apart from the initial costs of purchasing equipment, the most expensive items in the establishment and implementation of the system are staff time and travel (budget in Nordeco and DENR 1998a).

Field methods

Establishing and implementing the monitoring system comprises ten steps in each protected area (Table 3). For each indicator there is a corresponding field method.

The Field Diary method (Table 1) encourages protected area staff to be observant of changes in the use of park resources and the abundance of species. Data gathered by this method is difficult to correct for effort and can be easily biased – by a change in patrol routines, for instance.

The Photo Documentation method provides data that is independent of observer and identification skills (Table 1). It documents habitat changes and provides an insight into the cause. If negatives and prints are stored in a safe, dry place, they can last for many years. The photos can also be used for demonstration and education purposes.

The Transect Walk method (Table 1). Parts of existing patrol routes are used as survey routes whenever possible (instead of establishing new trails) and only observations, signs and spoor marks of a few preselected wildlife species and resource uses are recorded. As the capacity of the protected area staff improves, this method can be further elaborated (by estimating the perpendicular distance from the trail to each record) as it is a simplified version of the variable-distance line-transect method (Burnham and Anderson 1984; Buckland et al. 1993; Laake et al. 1993). The data might subsequently be used to reveal national trends in the population of priority species.

The Focus Group Discussion method draws upon Participatory Rural Appraisal (PRA) techniques developed by social scientists over the last decades. The strength of the Focus Group Discussion method is that it encourages a dialogue between

Table 3. Ten steps in establishing and implementing the biodiversity monitoring system in Philippine protected areas.

Step 1. Compile basic information on the protected area
Before you can establish and use the monitoring system you should have at least a rough idea of what the major threats are to the park and where they are most serious. In addition, you should know which parts of the area are particularly important to conservation and local use by park communities. These can for instance be areas known to support species of conservation interest, or where local people fish, hunt and collect non-timber forest and wetland products.

Step 2. Identify priorities for biodiversity monitoring
Identify those sites and those species and resource uses, which should be monitored. Discuss these with the Head of the Protected Area Office and other knowledgeable people, and decide which of those sites and species are the most important to monitor.

Step 3. Training
Ask the Protected Area Wildlife Division of the regional office of the Department of Environment and Natural Resources (DENR) for training in monitoring biodiversity and resource use. They may be able to provide a trainer, or they can get staff from other protected areas to assist you.

Step 4. Establish the biodiversity monitoring system
The monitoring system entails four field methods: the Field Diary method, the Photo Documentation method, the Transect Walk method and the Focus Group Discussion method. Look at the list of the most important sites and species you wish to monitor. Read the methods and identify which sites and species can usefully be monitored by each method. Your choice will depend on available time, number of park staff, funds and transport facilities. Establish monitoring sites in the field (Photo Documentation, Transect Walk, Focus Group Discussion). If necessary, prepare a simple guide for the field identification of your priority species, using available existing literature (see Nordeco and DENR 1998a).

Step 5. Compile data using the field methods
Use the field methods to compile data on biodiversity and resource use. Write a Field Diary whenever you travel in the park. Every quarter use the methods on Photo Documentation, Transect Walk and Focus Group Discussion.

Store the data sheets and photos carefully in ring-binders and photo albums at the Protected Area Office. Prepare copies of the Transect Walk data sheet and submit them to the Regional Protected Area Wildlife Division of the DENR for safe storage.

Step 6. Analyse data and identify trends
Once a year you should look at your data and try to highlight any changes over time. If there seem to be changes, you should assess whether the data is likely to reflect the true situation in the park, or if the data could be biased, e.g. by a change in monitoring routines or the weather.

If there seems to be a real change you should try to identify the reason for the change, the importance of the change, and then assess if any management intervention is appropriate. The reason for a change is often related to the human use of the area. The common impacts of human activities and typical causes of destructive activities in Philippine parks are described in Tables 4–6.

Step 7. Validate results with the protected area communities
Present findings to local people and ask for their advice. Use pictures and figures but very few words, and try to be as site-specific as possible. Do the local people consider the findings relevant? Also discuss possible actions to be taken by the people themselves, the Protected Area Management Board or the Local Government Units on the basis of your findings. Maintaining a dialogue with the park communities is an important part of the monitoring process.

Step 8. Present findings and recommended actions to the Protected Area Management Board
Present the most significant findings to the decision-makers in the Protected Area Management Board. Present corresponding options for action. How you display your findings is very important. Use graphs, figures and few words.

Table 3. Continued.

Step 9. Make decisions to improve protected area management Remember that the reason for spending time and money on monitoring biodiversity is to guide action in park management. You should encourage the Protected Area Management Board to take decisions on the basis of your findings. A list of possible management interventions is provided in Table 7.
Step 10. Revise and strengthen the monitoring system Assess whether the methods provided useful data or not, find out why, and then adjust the monitoring system. Perhaps a method generated too few data, or it did not cover the habitats you wanted it to cover. Perhaps some park staff were not fully committed to the work, and the task of monitoring biodiversity needs to be given to somebody else.

protected area staff and park communities regarding the status of park resources and management. Consequently, park communities are more likely to agree on, and participate in, law enforcement, regulation of resource use and reaction to encroachment by outsiders. In fact, this method seems to enhance local ownership of the monitoring system as well as of the protected area. For the Focus Group Discussion method, even the initial monitoring activities can provide useful results, as past changes in availability of resources may be memorized. The success of using this method, however, depends on the ability of protected area staff to communicate with local communities. Appendix 1 describes how protected area staff introduce the biodiversity monitoring system to the park communities. An example of a Focus Group Discussion in a community (Appendix 2) is provided. The method contributes to building capacity in environmental management as possible solutions to problems of environmental management will inevitably be aired when discussing changes in biodiversity.

Monitoring sites are chosen on the basis of the location of the most serious threats to unique biodiversity in the protected area, priority areas for conservation and resource use by local people, and accessibility. The Photo Documentation and Transect Walk methods are carried out both in areas with and without human use, so that the latter can serve as reference areas.

From field data to results

The Head of the Protected Area is responsible for ensuring that at the first meeting of the Protected Area Management Board each year, the results of the previous year's biodiversity monitoring are on the agenda.

All the methods assume that data is compared with *previous* monitoring data. Data organization, analysis and interpretation differ from method to method (guidelines in Nordeco and DENR 1998a). Some of the questions which have to be answered follow here:

Field Diary method. Have there been any changes in land-use or area and quality of habitats noted? Are there apparent changes in the distribution or frequency of

species or signs of resource uses? Have there been major changes in the numbers or distribution of records of target species or resource uses (the selected species and uses which should always be noted)?

Photo Documentation method. Do the photographs show any change in land-use or vegetation when compared with older photographs of the same area?

Transect Walk method. Does the data indicate any change in species abundance or resource use?

Focus Group Discussion method. Do the local communities experience any changes in the environmental benefits, the amount of a resource harvested, the time it takes to harvest a desired quantity of some resource, the equipment used, or the number of people involved in harvesting a resource?

It is important to assess whether the data is sufficiently extensive in order to ensure that an apparent change is not merely caused by chance. What appear to be large changes will often happen by chance when data sets are very small. For the Transect Walk method, simple statistical tests can be used to obtain an indication of the likelihood of changes in frequency of records reflecting real changes. Results from all methods may be biased by changes in weather, seasons or other natural background conditions. Other potential bias includes: changes in patrol routines or intensity of patrolling (Field Diary method); timing of the transect walks, the ability of the observers to detect wildlife species and resource uses (Transect Walk method) and changes in the composition of the Community Monitoring Group (Focus Group Discussion method). Interpretation should consider improvements of accuracy or efficiency from the first study period. Interpretation may also be complicated by spatial and temporal variations in biodiversity, which may be unrelated to the management of the area. In the Philippines there is currently very limited knowledge of these natural variations.

From results to management responses

The most challenging part of the biodiversity monitoring system is to move from results to identifying appropriate management responses. It is relatively easy to detect a change but much more difficult to find a cause (e.g. Wilson 1994). Since significant change in the biodiversity of a park is often related to the human use of the area, one needs to know what the likely impacts of different human activities are in order to identify the reason for the change. This will often be a matter of understanding whether change is caused by direct use of the species in question or by habitat modification which may affect whole communities.

In the Philippines, human activities which involve serious destruction of natural habitats include: logging using bulldozers and trucks, carabao (buffalo) logging,

swiddening, agricultural development, industrial development, mining and road construction. Human activities which normally involve only minimal destruction of the natural habitats but which may affect single species are: hunting, fishing and shellfish gathering and gathering of non-timber forest and wetland products. Whilst the latter four activities usually have limited impact on the natural ecosystems, there are exceptions in cases such as fishing using dynamite, poison or electricity. A summary of the common impacts of human activities in, or adjacent to, Philippine parks is provided in Tables 4 and 5. A special case is camping and hiking, which can sometimes cause severe disturbance (when it is targeted towards sensitive species or ecosystems such as coral reefs), but which usually has only very limited impact (although it may occasionally lead to the desecration of the sacred places of indigenous communities).

Identifying the appropriateness of any management response involves examining the typical causes of destructive human activities in Philippine protected areas (Table 6) and possible management responses (Table 7). For instance, indications of over-harvesting will require discussions with the villagers at a community meeting. Observations indicating rapid and serious decline in biodiversity (such as big tree stumps indicating large-scale logging) may need the immediate attention of the Head of the Protected Area. It is important to avoid hasty conclusions but also to be aware that the interest in participating in monitoring can easily be jeopardised if no management decisions are forthcoming on the basis of the monitoring system.

Table 4. A summary of the common impacts of logging, swiddening (kaingin), agricultural development, industrial development, mining and road development in, or adjacent to, Philippine protected areas.

1. *Increased access and in-migration*. Increased access to the interior of the park by new roads and trails, and increased in-migration and pressure on land for farming.
2. *Fragmentation of habitat*. Further degradation, fragmentation and destruction of the remaining small areas of natural habitat, which may eventually lead to the total disappearance of these habitats.
3. *Extinction of plant and wildlife*. Decline in the diversity and population of plants and animals of importance to conservation and local use. For instance, many threatened species are found in lowland forest, and some occur only in this habitat; those species would become extinct in the park if the remaining lowland forest disappears.
4. *Deterioration of watershed functions*. Through destruction of the vegetation cover, further deterioration of watershed functions and increased occurrence of floods, landslides, soil erosion, siltation, poor quality of potable water, incidence of fires, and a dryer and hotter micro-climate.
5. *Decline in fish stocks*. Sedimentation of rivers and coastal waters leads to a decline in stocks and diversity of riverine and marine fish and degradation of coral reefs and sea grass beds, which are spawning and nursery areas for fish and crustaceans.
6. *Marginalisation of local communities*. Local communities, directly dependent on a diversity of forest and wetland resources, become increasingly marginalised and forced to adopt intensive extractive activities.
7. *Damage of crops*. Destruction of natural habitats may dislocate animals and drive them to infest or feed on crops.
8. *Water pollution*. Mining and agricultural development such as high value crop plantation may contaminate water sources.

Table 5. A summary of the common impacts of hunting, fishing and gathering of non-timber forest and wetland products when used beyond sustainable levels.

1. *Decline in availability of resources*. Decline in availability of plant and animal resources which are important for local food and income.
2. *Decline in populations of threatened species*. Decline in local populations of species of plants and animals, which are important to conservation.
3. *Increased competition for resources*. With the decline in resources, people need to travel further into the park to find the resources, and harvesting methods become increasingly destructive. Competition over the use of resources intensifies. Most affected are the indigenous people and poorer households, who are further marginalised.

Role of biodiversity in performance monitoring of conservation project

The Conservation of Priority Protected Areas Project (CPPAP) seeks to conserve biodiversity in ten priority protected areas in the Philippines. The biodiversity monitoring system has been integrated into this project's performance monitoring plan which serves the purpose of indicating whether or not the project achieves its objectives (Pollisco-Botengan 1997). The four indicators of the biodiversity monitoring system (Table 1) are used as indicators for the Development Objective of CPPAP ('to conserve biodiversity'), while the associated methods are the Means of Verification. The success of the project is assessed by summing up the local experiences. For evaluation exercises involving local people the results are expressed in trends and not in numerical indices or absolute figures. Since the biodiversity monitoring system was only recently incorporated into the monitoring of CPPAP, its usefulness for performance monitoring still remains to be seen.

Evaluation of how the biodiversity monitoring system is implemented

The success or otherwise of this biodiversity monitoring system will be evaluated on the basis of an assessment of the implementation of the system and its impact. We will use the following criteria for assessing implementation:

- Is the system in operation in those parks where it was established;
- Are the field methods used in accordance with prescriptions;
- Is the generated data stored in a systematic and safe manner;
- Is data regularly being analysed and presented to decision-makers;
- Are wildlife species properly identified, and are sufficient notes made to document observations of rare species;
- Number of park staff who record routine observations of wildlife and resource use in writing;
- Number of established and surveyed Photo Documentation sites and Transect Walk routes, and number of Community Monitoring Groups and Focus Group Discussions and village meetings undertaken;

Table 6. Typical causes of destructive human activities in Philippine protected areas.

Destructive human activities in, and adjacent to, parks are often caused by:

1. *Inadequate co-ordination between government agencies*. The National Integrated Protected Areas System (NIPAS) Act is sometimes implemented in isolation from other development programmes in and around the park because of inadequate co-ordination between different government agencies and an unclear division of authority. Sometimes the Head of the Protected Area Office and the Protected Area Management Board are not, in practice, in control of the provision of land use permits, rights or titles to land in the park; these may be controlled by Local Government Units and other government agencies, which do not prioritise the NIPAS Act.
2. *Unclear demarcation of management zones*. Insufficient on the ground demarcation of Alienable and Disposable zones, park boundaries and zoning to guide people on what activities to undertake where.
3. *Lack of security of tenure over land.* Lack of security of tenure over land on the part of park communities encourages land speculation and creates opportunities for people to claim new land by opening up swiddens. It is a disincentive to investing in sustainable land use (i.e. conservation measures, soil fertility improvement) and it leaves park communities powerless in trying to prevent people from expanding destructive human activities in the forest areas.
4. *Limited environmental information available*. Destructive practices may not be recognised if there is a lack of knowledge among park communities and park staff regarding local environmental issues, for instance, the status of threatened species and the relationship between forest degradation and the productivity of coastal and other ecosystems.
5. *Insufficient and inappropriate monitoring and enforcement*. Park rangers may lack appropriate training and operational funds to implement the law. In addition, there may be a poor relationship between enforcement rangers and park communities and no participation of local people in monitoring and enforcement. Rangers may be seen by locals as concentrating their enforcement efforts on local people's use of timber and non-timber forest products for household consumption rather than apprehending those involved in the commercial cutting of timber and other more destructive human activities.
6. *Minimal follow-up on legal actions against major offenders*. In some areas, a large proportion of people may depend on big companies for employment and social services and the commercial sector is, to a large degree, in control of the economy. Consequently, if these companies seriously violate the NIPAS Act, they may not be brought to court, or there may be no follow-up to legal actions. Sometimes, local government agencies may be involved in, or protecting, seriously destructive human activities in the park, which makes enforcement even more difficult.
7. *Other reasons*. Other important causes – particularly for swiddening (kaingin) – are poverty, a decline in land area available for swiddening, and few cash-generating livelihood options for the park communities. Traditionally swiddening was a fairly sustainable practice, but today it has become unsustainable in many areas due to a decline in the land area available for farm plot rotation and a decrease in the use of traditional soil conservation measures. Swiddening is rooted in poverty, a lack of alternative farming practices and limited income generating possibilities. In many areas, communities are forced to open swiddens in foothills and uplands because of a shortage of permanent fields in the valleys, increased incidence of flooding and periods of drought and depleted soils. Added to these problems are a lack of skills in alternative agricultural practices and a preference among many people for a livelihood derived from a combination of small-scale logging and cultivation, rather than permanent farming.

- Number of occasions where photos from the Photo Documentation method are used for demonstration or education purposes.

For assessing the impact of the system we envisage using the following criteria:

- Do protected area staff and Protected Area Management Board continue to use the biodiversity monitoring system;

Table 7. A list of possible management interventions in Philippine protected areas.

Typical management responses could be to:
1. Disseminate information to relevant authorities on the conservation needs and problems faced by the park due to encroaching development projects and discuss and agree on solutions. The Protected Area Management Board (PAMB) may find it necessary to make recommendations for the Secretary of the Department of Environment and Natural Resources (DENR) to take action.
2. Strengthen co-ordination amongst the government agencies involved in resource use and conservation in, and adjacent to, the park.
3. Delineate park management zones and boundaries by mapping, ground truthing and monumenting. Establish areas in the vicinity of communities which will be for the sole use of people from these communities. These areas should accommodate their needs for fishing, hunting and forest product gathering and, within a smaller part of this area, farming and household supply of timber. Establish agreements on land use and quotas and state criteria for adherence to the agreed land and resource use in a contract.
4. Support a fast and efficient processing of 'tenured migrant instruments' and 'ancestral domains' so as to provide an incentive for the sustainable use of the land, minimise land speculation, and encourage park communities to keep people from expanding destructive activities in forest areas.
5. Raise awareness among local communities of specific conservation needs, the role of local people in park management and observed destructive practices in resource and land use.
6. Strengthen staff capacity. Further train, support and deputise local forest guards. Strengthen capacity of enforcement rangers in community approaches such as style of communication and establishing dialogue with community members. PAMB may find it necessary to recommend to DENR that they obtain more operational funds.
7. Discuss and agree with park communities and Local Government Units on the establishment of a system of closed season, quotas or zones for hunting and gathering of selected species. In addition, discuss and agree with park communities and Local Government Units on the prohibition of capture, trade and possession of products from the most endangered species.
8. Encourage municipalities to issue by-laws supporting park regulations and PAMB resolutions.

- Number of women, indigenous and other local people who participate in village meetings to discuss monitoring results;
- Opinion on the biodiversity monitoring system by different groups of end-users;
- Number of occasions where monitoring results are being used by local communities, park staff or the PAMB;
- Number of examples of reaction to encroachment by outsiders on the part of the protected area communities;
- Number of management interventions implemented, based on results of the biodiversity monitoring system.

Power of the Transect Walk method to detect a trend

In order to judge the power of the Transect Walk method to monitor trends in the abundance of Philippine forest wildlife species, we used a series of five replicated transect walks carried out by the authors during a project of DENR and BirdLife International in Northern Sierra Madre in 1991–1992 in order to determine the precision of this method. On the basis of these replicates, the coefficient of variation of

a single census of, e.g., Red Junglefowl *Gallus gallus* was estimated to be 0.55. We used the program TRENDS developed by Gerrodette (1987, 1991) and assumed that population change is linear, that the coefficient of variation is inversely proportional to the square root of the abundance, and that the distribution was standard normal (z). We assumed that data will be analysed at the $\alpha = 0.05$ significance level (two-tailed). With four censuses made each year, the probability of detecting a 20% per year change in abundance after three years is 0.15, while after seven years the probability is 0.81. In other words one should not be overly optimistic: for the Transect Walk method to be able to detect a trend with a statistically acceptable degree of confidence a long period is needed.

Constraints

By 1999, the biodiversity monitoring system had been established, tested and revised in the three protected areas and was in almost full operation. The main constraint has been insufficient institutional support for implementing the system. Biodiversity monitoring is a new activity, which until 1999 did not figure in the annual work plans of DENR. It is not included in the job description of the park staff and only from 1999 will there be government funds available for transport and other costs. Another constraint has been the limited management skills of some park staff. Some staff have difficulty in organizing themselves before going to the field, e.g., ensuring enough food and water, and in arranging that field data are copied, filed and stored properly.

Discussion

Necessary further development of the Philippine monitoring system

The DENR of the Philippine Government would like to expand the biodiversity monitoring system to 184 protected areas (DENR 1998). We have suggested that it be first established and further tested and refined in a small number of sites so that revisions needed in the approach, methodology and in the list of species and resource uses for monitoring can be identified (see e.g. Simberloff 1998). We have proposed the following criteria for selection of further sites:

1. their combined coverage of Philippine flora and fauna,
2. the interest of protected area communities in cooperating with government staff on resource management,
3. legislative status and field personnel available (sites should have protected area status and staff),
4. coverage of the administrative regions of DENR, and
5. the law and order situation.

There is a need for a national policy on biodiversity monitoring and a directive to the regional and provincial offices of DENR. In each protected area, biodiversity monitoring should be incorporated into annual work and financial plans, equipment should be purchased if not already available, and biodiversity monitoring should become part of the job description and performance evaluation of park staff. We suggest that specific staff from the Protected Area and Wildlife Bureau of DENR be given responsibility for overseeing the implementation and supervision of the biodiversity monitoring system. Staff from each protected area and some members of the local NGOs and communities should be trained in the monitoring system, and the system should be installed on the sites. National and regional staff of PAWB-DENR should be trained in supervising its installation and implementation. Biodiversity monitoring training should be fully accredited by DENR and integrated into their existing training systems. In addition, field guides for the identification of priority species and resource uses in other parts of the Philippines need to be developed. Partnership between park staff and universities should be promoted. Park staff and local academics should be encouraged to present results of monitoring in national meetings, in conference proceedings, newsletters, scientific journals and local and national newspapers in order to stimulate discussions and increase awareness on biodiversity conservation and the importance of biodiversity monitoring. PAWB should regularly prepare a national synthesis report for decision-makers and the broader public on the results of the monitoring in order to provide an overview of the knowledge of trends in biodiversity and resource use.

It was unfortunately not possible for us to conduct methodological studies to document to what extent the parameters collected reflect changes recorded by more standardized methods. In the Natural Parks of Northern Sierra Madre and Mt. Kitanglad Range however universities are currently establishing permanent vegetation plots, which we hope on long term can be used for comparison.

Minimum starting point

For forest biodiversity monitoring programs to be able to provide unequivocal answers, Margules et al. (1998) identified a number of important elements:

1. controls in areas with no human activity,
2. replication in sampling to account for spatial heterogeneity and random variation,
3. knowledge of conditions before human activity began,
4. environmental stratification to capture the habitat preferences of specialized species and facilitate analyses of the responses of less abundant species,
5. a sufficient period of monitoring to establish human use effects and distinguish them from climatic fluctuations or other episodic events, and
6. replication at more than one location to avoid location-specific phenomena.

In the Philippine monitoring system, controls in unused or largely unused areas (1) are made for the Photo Documentation and Transect Walk method where undisturbed

forest areas are easily accessible. Replication of sampling (2) is undertaken in the Photo Documentation, Transect Walk and Focus Group Discussion methods, as these methods are applied on several sites in each protected area. The monitoring system does not establish knowledge of pre-human use conditions (3), since this would be logistically very difficult and human use of Philippine protected areas cannot be regulated as in an experiment. Environmental stratification (4) is made for the Transect Walk method where data is compiled on the location of vegetation types and records of species and resource uses along the transect. The monitoring system is expected to continue for a long period (5), and the monitoring system is replicated in several protected areas (6).

In the Philippine system, we have not included all those elements that are desirable for monitoring programs but we have shown what monitoring can be undertaken in practice by protected area staff and local communities. Many recent attempts to establish biodiversity monitoring systems in developing countries have run into serious trouble because the systems were too large and complicated. For instance, in the Tarangire National Park, Tanzania, the University of Milan assisted the government by monitoring wildlife migration routes using radio-telemetry and 'GIS'. Funds, however, ran out rendering the high technology useless. The project is now simplifying all monitoring routines so that they can be sustained with minimal funds and a small number of government staff (V. Galanti, pers. com.).

The Philippine biodiversity monitoring system was developed bearing the typical problems of developing countries in mind, including those relating to high numbers of species, incomplete taxonomic knowledge, few economic resources and large total size of protected areas. We consider this monitoring system as a feasible minimum starting point, which can evolve further over time as more resources and skilled people become available to manage and monitor biodiversity. As long as the procedures of the four methods are continued on the same sites (and by the same persons, especially for the Transect Walk method) development of the system does not significantly violate the assumption for monitoring that quality and reliability of data sampling remain unchanged. Further development of the system may include adding methods and storage and analysis of biodiversity data on computer. Studies of the habitat requirement and ecology for the target species will increase their value as indicators for biodiversity. The records from transect walks can be related to population density if estimates are made of the perpendicular distance from the trail to each record to correct for visibility bias. This need only be done until the relationship between frequency of records and population density is understood. Data compiled on a geographical basis (with latitude and longitude) can be entered into a computerised 'GIS'-database, if and when this is appropriate. We anticipate the current methods being backed up by remote sensing of land-use and vegetation on a regular basis, as well as by in-depth monitoring of selected habitats, species and sites.

Participation of local communities in biodiversity monitoring

Until the late 1980s it was a maxim of practical conservation in developing countries that biodiversity was best conserved by establishing strict protected areas. This resulted in many conflicts with local communities who depended on the natural resources of the areas. It was morally impermissible in many places, and it was costly and difficult (or impossible) to enforce regulations. The real threats to biodiversity often come from organised elites or other non-local residents, and long established local people frequently have strong interests in conserving their resource base.

By the beginning of the 1990s, many policy and decision-makers therefore abandoned this 'fines and fences' approach in protected area management and instead attempted to provide positive incentives through alternative income-generating strategies aimed at reducing dependence on natural resource use. However, in most developing countries, at least in Africa (Brown 1998) and South East Asia (e.g., Danielsen and Enghoff 1999), this approach has also generally proved ineffective. Instead, the way forward in protected areas with long established local communities probably lies in the consolidation of existing livelihoods in the protected areas through strengthening non-destructive natural resource management systems and supporting partial exclusion of non-traditional resource users and users of external origin. The biodiversity monitoring system plays a role in reinforcing this strategy in Philippine protected areas.

The communities expected to participate in the Philippine monitoring system are the indigenous people and migrants who live in and adjacent to the protected areas. These people take decisions on resource management every day in the field, often far away from park staff, municipal officials and others at higher levels. These decisions are imperative for the future of the protected areas and should inform higher level decision-making.

These people are expected to provide information on resource use and wildlife to the protected area staff (Field Diary method) and take part in discussions of photos of habitats and land-uses (Photo Documentation method). In addition, they are supposed to collect biodiversity relevant information, present and discuss this with other local people and park staff and agree on and take part in law enforcement and regulation of resource use (Focus Group Discussion method).

As of 1999, the role of local communities in monitoring has, however, been limited largely to collecting information and taking part in discussions with park staff. The ability of the Focus Group Discussion method to encourage shared management of the parks' resources with local communities has only partly begun to be utilized. There are several reasons, which we try to address in the revised training courses.

It is relative easy and straight forward to take photos or walk transects. One merely needs to follow the 'recipe' (and be able to identify species on the transect). Facilitating Focus Group Discussions for the purpose of monitoring biodiversity requires reflection and an independent way of thinking on the part of the park staff if they are

to be able to respond in a constructive manner to what the members of the Community Monitoring Groups say.

Training is also difficult. You can walk a transect twice to become better at it but you cannot repeat community meetings. A community meeting requires a lot of time for many people. During training it rarely was possible to conduct a community meeting because people had limited time in settlements within reach of the training venue. In addition, it was difficult to find Philippine socio-economists with the appropriate experience and ability to conduct such training.

Most park staff had minimal previous exposure to socio-cultural issues, to participatory methods and to entering into dialogue with local communities, in part because many had as the point of departure of their career the 'fines and fences' approach. Park staff used to see local people as potential offenders of the park regulations. Some might have been reluctant to hand over control of resources to local people. It has been difficult for park staff to understand and accept the basic strategy for this method of sharing insight and knowledge with 'normal' community members and of accepting the subjective statements of community members as being of value to monitoring. Staff are used to dealing with outspoken and influential people in the communities. They sometimes have difficulty in communicating effectively with the lower level stakeholders such as indigenous negritos (Agtas) and others who depend most directly on the use of minor forest and wetland products. It does not help that many park staff have witnessed earlier externally-funded projects, which formally emphasized the assignment of active key roles to local stakeholders but in reality limited the role of 'the beneficiaries' to the subjects of consultation and passive reception of training and inputs. In addition, Focus Group Discussions are very time-consuming in the short run. With the time constraints of the park administrations, low priority was sometimes given to this method.

Potential for application in other countries

The potential for using the present approach to biodiversity monitoring in other countries depends on the government's strategy for park management, the importance of forest and wetland resources to the rural people and the availability of human capacity and financial resources for protected areas. The system is particularly useful when a government is embarking on a policy of shared management of park resources with local communities, when a large proportion of the rural population depends on forest and wetland products (and where they have a long history of settlement and attachment to the areas) and when there is limited available human capacity and funds for protected areas.

Most protected areas in developing countries fall within this category. In these cases, the approach of the Philippine monitoring system may be readily applicable, but the management objectives of the protected areas may differ. In addition, there will be different species and resource uses, different destructive human activities and

different appropriate management interventions. In countries where most natural habitats have been converted to other land-uses, few people depend on resources from these habitats. Communities would generally have little or no incentive to participate in this kind of biodiversity monitoring, and it would be difficult to encourage people to participate. Where protected area staff have very minimal education and government funding but the relationship between park staff and local communities is generally good (e.g. in Lao PDR), very useful results may be achieved by the Focus Group Discussion method, and biodiversity monitoring may be limited to this and the Field Diary method.

In any case, we recommend that other countries develop their own biodiversity monitoring system with park staff and representatives of park communities. We suggest that:

- The process of developing the biodiversity monitoring system should involve protected area staff and representatives of park communities;
- The monitoring should be focused at the field level, where the management decisions are taken (c.f. the principle of subsidiarity in capacity development in environment; Boesen and Lafontaine 1998);
- Equal priority should be given to bio-physical and socio-economic information;
- The monitoring system should encourage a dialogue between all stakeholders in protected area management, and it should build bridges between local resource management systems and the natural resource management agencies;
- It should be kept simple and practical, so that methods can be easily integrated into the other work activities of the field staff and the system can be continued with locally available resources.

The development of the system in the Philippines has taken 3 years. It could have been done faster, but only at the expense of the process itself being a means for development of capacity, and the creation of ownership of the monitoring system at the field and at national agency level being facilitated (c.f. OECD/DAC 1997). Strong ownership is a prerequisite for sustaining biodiversity monitoring in the long-term.

Protected areas cover 4.6 million square kilometres in Asia, Africa and Central and South America (WRI et al. 1998). A large proportion still exist largely on paper (see e.g. Schaik et al. 1997). If the process of developing and implementing simple biodiversity monitoring systems can contribute to strengthening the management of just a small proportion of these sites, this would be an important achievement.

Acknowledgements

The development of this biodiversity monitoring system was part of the ‘Technical Assistance to Improve Biodiversity Conservation in Protected Areas of the Philippines’, which was undertaken by Nordeco in collaboration with PAWB-DENR and

NIPA, Inc. The project was funded by the Ministry of Foreign Affairs of the Government of Denmark, and managed by S. Shen of the World Bank (Grant No. TF020792). We are grateful to the protected area staff and the local communities in Mt. Kitanglad Range Natural Park, Bataan Natural Park, and Northern Sierra Madre Natural Park for participating in discussions and field testing of the system. We also thank the following who assisted with the system development: R. Altamirano, P. Alviola, M.A. Barcelona-Leones, E. Batangan, J. David, A. Diesmos, R. Fernandez, R.T. Fragata, G. Gee, M. Heegaard, A. Manamtam, F.S. Mirasol, S.S. Nielsen, E. Paring, E.L. Pimentel, S. Pullarca, M.F. de los Reyes and R.J. Schoen. Comments were received from H. Acquay, M. Agayatin, A. Andres, W. Balilia, R.C. Bayabos, E. Bonilla, L. Calanog, P. Calimag, I. Castillo, N. Corpuz, C. Custodio, G. Garcia, M. Hawkes, M. Hidalgo, A. Khan, T.M. Lim, N. Lita, A. Manila, M. Mendoza, A. Meniado, G. Morgan, P.d.v. Moss, N. Moulinyawe, V. Palaganas, H.B. Pedersen, R. Pine, W.S. Pollisco, M.A. Pollisco-Botengan, J.F. Rasmussen, P. de los Reyes, G. Roscel, A. Tagtag and C. Ulep. The language was corrected by E.D. Bolton. We are grateful to R. Altamirano, J. Fjeldså, L.L. Sørensen and T. Whitten for their comments on drafts of this paper.

Appendix 1. How protected area staff introduce the biodiversity monitoring system to the park communities.

Park communities may be interested to participate in biodiversity monitoring if the park staff can generate trust and establish reliable two-way communication with them. Below we describe how park staff introduce themselves and the biodiversity monitoring system to the local communities.

1. Introduce yourself (name, job, where you come from).

2. Explain how the park has been established and what will happen in the future.
The Philippine government decided in (year) that the area you are living in and the area within (name of geographical features) shall be an area in which the use of the natural resources shall not destroy the resources in the long term, and where conservation is very important. This area is called (name). I, together with other park staff in the area, have been given the responsibility of working with you for the best conservation and use of the area. It is the policy of the government that collaboration between you and us, both expressed by park staff working directly with you and by the working of the Protected Area Management Board as representing your interests, is the best way to make sure that the park remains with good forest cover/water quality/wetland resources and with many different animals and plants when your children and their children grow up.

3. Describe the reason for establishment of the park.
The park was established because it is one of the few remaining areas in the country with good forest/wetlands which are important for providing a clean and stable supply of water, and because it is home to animals and plants that have been wiped out in most other places in the country and in the world (name a few). The area is also providing many benefits such as fish, animals and forest products to many people in the area. The government wants to ensure that this unique area is not disappearing and is for the benefit of both you and people in the country as a whole.

Appendix 1. Continued.

4. Explain how the park staff will work with villagers.

We will be able to work with you in order to assist you in seeking ways:

- of using the wild plants and animals in your area in such a manner that they are not disappearing,
- of better protecting the forest from destruction,
- of improving protection of those wild animals and plants that are getting very rare such as (name a few),
- of improving the methods for farming, use of forest/wetlands, hunting and fishing in such a way that they are not destroying the forest and wetlands,
- of securing your rights to use the land, water, forest products and wild animals in your area within certain limits and in a way that is approved by the Protected Area Management Board and Local Government Units.

We are able to do this by visiting your village frequently to discuss, maybe advise and hopefully assist you during the coming year and perhaps longer.

5. Explain the objectives and activities of the biodiversity monitoring system.

I have come to your village today because we would like to know if you will work with us to observe changes in the numbers of wild plants and animals and in the use of the forests and/or wetlands for the best conservation and use of the area. If you are interested, we would like to find 10–15 local people who are willing to collect data on wild plants, animals and resource use, and who will spend two hours with me every quarter so that I can listen to, and we can discuss, their observations. It is best if those people are involved with community work within natural resource management (forest guards, community forestry committee members, etc.) or villagers otherwise interested in the use of forest/wetland resources. We would like the most experienced indigenous healer and all-round hunter/forest product gatherer to be members of this group (explain possible issues you would like them to look for but say that they might have better suggestions). Every year or so we would also like to discuss the findings with the whole village so that we can tell them about your findings and get input and responses from all members of the village.

6. Describe how the park staff will work in other ways.

We will also work in other villages, and we will work, both here and in other places, on issues such as: trying to stop commercial hunting and gathering by outsiders, trying to prevent developments that will destroy the park, co-ordinating with other agencies, preventing large-scale logging, providing information to park communities and others, etc.

Appendix 2. Description of a Focus Group Discussion in a protected area community.

The discussion took place in a village located partly inside a park and inhabited by both migrants and indigenous people. People in the village practise both swiddening (kaingin) and permanent agriculture. Small-scale logging, fishing, hunting and gathering of non-timber forest products are important activities for part of the population.

The main problems of natural resource management in the village are: decreased access to non-timber forest products, decreased fishing and hunting, logging supported by outside business people, less availability of clean water, occasional flooding, constraints in availability of land for agriculture, unclear rights to land and resource use inside the park.

The discussion lasted about one hour. Five members of the Community Monitoring Group and two park staff participated.

A monitoring group has been established in the village and has, in consultation with park staff, decided to concentrate on monitoring:

- the number of people involved in rattan collection for sale at market and the change in time needed for people to collect a bundle of good quality rattan;
- the change in effort needed for collection of durian from the forest and for collection of orchids from the montane forest;

Appendix 2. Continued.

- the expansion of hectarage of land under swiddening in a specific upper watershed inside the park;
- the change in number of households in the village with land under agriculture inside the park;
- the number of new tree stumps above 30 cm in diameter in a specific area of good quality lowland forest inside the park;
- the number of days that water from two specific streams is considered to be undrinkable because it is not clean enough or because it has dried out;
- the number of days/hours needed by selected expert hunters to hunt one wild pig or one deer;
- the change in size of fish and shellfish caught in specific streams and wetlands;
- any sightings or reports of Philippine Eagle and all sighting of hornbills in the valley behind the village inside the park.

For the above monitoring, the monitoring group in the village depended on information from the other villagers and on their own collection of data. Two people in the monitoring group noted the data in a notebook.

The discussion started with the park staff reporting back to the group on how the issues they discussed three months ago have been developing and whether any management actions have been undertaken or decided by the park or the Protected Area Management Board. The main issue was the protection of the upper watershed of one of the mountains in the park from further clearing for coffee growing and the decision on a closed season for hunting deer in the park.

The park staff then reported to the group on how the data they discussed last time had been handled, whether any common aspects were found with other villages and whether any new trends had been discovered or any existing trends reinforced.

The main issues were that data on hunting was too unevenly collected to be reliable and that collection must be more continuous by talking to the same hunters at regular intervals. It now seems that improvements in the size of fish was quite consistent in the data for the last year. In general in the park this is quite unique and seems to be related to the villagers imposing regulations in the major fishing stream and wetland in their area. In other streams in the park the size is decreasing. The data on quality of water in one of the two streams in the village has now shown a decline as compared to the same time last year because more days with dirty water have been reported; this is consistent with other villages in the park.

It was then discussed as to whether the monitoring group, which now only consisted of six members, was still able to monitor as many different aspects as before. The park staff reported that in other areas the monitoring groups had decided to collect less data by concentrating on fewer aspects, but the group felt that they could still manage.

Following this, the chairman of the group presented the monitoring data from the last three months. Unlike last time, when they copied the data from their notebooks to the park staff, they had not had the time on this occasion so it was decided that one would sit with the park staff after the meeting in order to copy the data.

The monitoring data follows:

- the number of people collecting rattan remains unchanged. One of the collectors reported that during the last three months she had had to increase her time for collection; others reported no change over the last three months;
- no durians were collected (not the season);
- data on orchid collection was still not easy to obtain, but at least two outsiders have been seen with orchids and one new businessman has approached the villagers to buy one very special orchid only found in the montane forest;
- the hectarage of land under kaingin remains unchanged, but a number of households in the village are preparing for clearance of some good quality forest in the watershed, as they have too little land available. Discussions with the monitoring group are taking place;
- one new household is now farming inside the park. As a newly married son of one of the families, he has received part of the cultivated family land. One family from outside the village has been asking for permission to open up land in the area; status of application not known;
- ten new tree stumps were reported (size ranging from 30 to 85 cm in diameter, with 5 from 30–40 cm, 1 of 50 cm, 3 between 60–70 cm, and 1 of 85 cm);
- two days with water too dirty for drinking were reported in one of the streams. In the other stream no dirty water was reported. No floods or drying out of streams were reported;

Appendix 2. Continued.

- hunting data was from one hunter who went on three hunting expeditions during the period, it took him two days to get one pig on the first, four days on the second and he did not get any on the third. He claims that hunting has become more difficult but that this has been so for many years and there has been no change during the last quarter;
- size of fish and shellfish caught remains unchanged according to people fishing in the village. On two trips to the river, three people from the monitoring group measured the size of the catch of people fishing with nets and hooks and the size of shellfish. The measuring data is in the notebook;
- number of hornbills sighted by members of the group in the valley seem to show that more hornbills are being found. On two trips to the valley that lasted one day each to collect rattan, one of the group members saw or heard 23 hornbills (15 one day and 8 the next). Other people also report more hornbills over the last quarter. One person in the village claims that he has seen a Philippine Eagle or at least a very big bird of prey.

The monitoring data was then discussed. The data on orchids collected needs to be improved. There must be more efforts made to ask other villagers what, and how much, they collect. Contact with more hunters should be established on a more regular basis. The data on hornbills should be compared to see if there is fruiting of specific trees found in the valley as this will attract hornbills and might explain the apparent increase in numbers. The sighting of a Philippine Eagle should be treated with care, as it can be fairly difficult to distinguish the Philippine Eagle from other large birds of prey. The most significant data is probably the number of big stumps (above 60 cm in diameter) found in the forest.

Problems of monitoring were then discussed and the group expressed a need for training in monitoring and for having an opportunity to share experiences with other monitoring groups in the park. Moreover, some material support such as pencils, paper, a pair a binoculars and a small per diem for the chairman of the monitoring group who spends a lot of time on the work, were discussed. The park staff member agreed to look at the issues with the park management.

Following this, some major management issues were discussed. Specifically, the issue of increased pressure to open up new agricultural land inside the park and the increased demand for orchids were discussed. Also, the possibility of extending the fishing regulations imposed by the villagers to the other stream near the village was discussed. Moreover, the reasons for increased logging of large logs were discussed and possible mitigating measures were looked at. The meeting ended, and a tentative new date for the next meeting was agreed upon. The park staff member ended by congratulating the group on the good work they had been doing.

References

Alder D and Synnott TJ (1992) Permanent sample plot techniques for mixed tropical forest. Tropical Forestry Papers 25: 1–124

Bibby CJ, Burgess ND and Hill DA (1992) Bird Census Techniques. Academic Press, London

Boesen J and Lafontaine A (1998) Indicators and monitoring of capacity development in environment initiatives. In: Danida and DANCED International Workshop on Danish Assistance to Capacity Development in Environment, Snekkersten, Denmark 12–14 May 1998, Workshop Proceedings, pp 96–130. Danida and DANCED, Copenhagen

Brown D (1998) Participatory biodiversity conservation rethinking the strategy in the low tourist potential areas of tropical Africa. ODI Natural Resource Perspectives 33: 1–5

Brown M and Wyckoff-Baird B (1992) Designing Integrated Conservation and Development Projects. Biodiversity Support Program. WWF, Washington, DC

Buckland ST, Anderson DR, Burnham KP and Laake JL (1993) Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, New York

Burnham KP and Anderson DR (1984) The need for distance data in transect counts. Journal of Wildlife Management 48: 1248–1254

Coddington JA, Griswold CE, Dávila DS, Peñaranda E and Larcher SF (1991) Designing and testing sampling protocols to estimate biodiversity in tropical ecosystems. In: Dudley EC (ed) The Unity of

Evolutionary Biology: Proceedings of the Fourth International Congress of Systematic and Evolutionary Biology, pp 44–60. Dioscorides Press, Portland
Dallmeier F and Comiskey JA (eds) (1998) Forest Biodiversity Research, Monitoring and Modeling: Conceptual Background and Old World Case Studies. Parthenon Publishing, Paris
Danielsen F and Enghoff M (1999) Fredet natur – mellem udnyttelse og beskyttelse. Den Ny Verden 32(4): 74–81
DENR (1992) National Integrated Protected Area System Act R.A. No. 7586 and Implementing Rules and Regulations DAO 25, Series of 1992. DENR, PAWB, Manila
DENR (1998) Medium Term Development Plan for the Protected Area and Wildlife Sector of DENR 1999–2004. DENR, Quezon City, Philippines
DENR and UNEP (1997) Philippine Biodiversity. An Assessment and Action Plan. Bookmark, Inc., Makati City, Philippines
Fuller J (1998) Participatory monitoring of forest resources: current methodologies being developed in Thailand. Rural Development Forestry Network 23e: 23–27
Gerrodette T (1987) A power analysis for detecting trends. Ecology 68: 1364–1372
Gerrodette T (1991) Models for power of detecting trends – a reply to Link and Hatfield. Ecology 72: 1889–1892
Groombridge B (ed) (1992) Global Biodiversity. Status of the Earth's Living Resources. World Conservation Monitoring Center. Chapman and Hall, London
Groombridge B and Jenkins MD (eds) (1996) Assessing Biodiversity Status and Sustainability. WCMC Biodiversity Series No. 5. World Conservation Press, Cambridge
Harmon D (1994) Coordinating Research and Management to Enhance Protected Areas. IUCN, Cambridge
Hammond A, Adriaanse A, Rodenburg E, Bryant D and Woodward R (1995) Environmental Indicators: A Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development. World Resources Institute, Washington, DC
Hellier A, Newton AC and Gaona SO (1999) Use of indigenous knowledge for rapidly assessing trends in biodiversity: a case study from Chiapas, Mexico. Biodiversity and Conservation 8: 869–889
IBAMA (1998) International Workshop on Biodiversity Monitoring in Federal Protected Areas: Observations and General Remarks. www.erols.com/dsbaker/
IUCN (1996) 1996 IUCN Red List of Threatened Animals. IUCN, Gland
Kremen C, Merenlender AM and Murphy DD (1994) Ecological monitoring: a vital need for integrated conservation and development programs in the tropics. Conservation Biology 8: 388–397
Kremen C, Raymond I and Lance K (1998) An interdisciplinary tool for monitoring conservation impacts in Madagascar. Conservation Biology 12: 549–563
Laake JL, Buckland ST, Anderson DR and Burnham KP (1993) Distance User's Guide, v. 2.0. Colorado Cooperation of Fish and Wildlife Research Unit, Colorado State University, Fort Collins
Margules CR, Austin MP, Davies KF, Meyers JA and Nicholls AO (1998) The design of programs to monitor forest biodiversity: lessons from the Wog Wog habitat fragmentation experiment. In: Dallmeier F and Comiskey JA (eds) Forest Biodiversity Research, Monitoring and Modelling: Conceptual Background and Old World Case Studies, pp 183–196. Parthenon Publishing, Paris
Margoulis R and Salafsky N (1998) Measures of Success: A Systematic Approach to Designing, Managing and Monitoring Community-Oriented Conservation Projects. Adaptive Management Series, Biodiversity Support Program, Washington
Nordeco and DENR (1998a) Biodiversity Monitoring System Manual. DENR, Manila; Nordeco, Copenhagen
Nordeco and DENR (1998b) Integrating Conservation and Development in Protected Area Management in Northern Sierra Madre Natural Park, the Philippines. DENR, Manila; Nordeco, Copenhagen
Nordeco and DENR (1998c) Integrating Conservation and Development in Protected Area Management in Bataan Natural Park, the Philippines. DENR, Manila; Nordeco, Copenhagen
Nordeco and DENR (1998d) Integrating Conservation and Development in Protected Area Management in Mt. Kitanglad Range Natural Park, the Philippines. DENR, Manila; Nordeco, Copenhagen
Noss RF (1990) Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4: 355–364

OECD/DAC (1997) Capacity Development in Environment: Proceedings of a Workshop held in Rome, Italy, 4–6 December, 1996. OECD, Paris

PAWB-DENR (1998) The First Philippine National Report to the Convention on Biological Diversity. PAWB-DENR, Quezon City, Philippines

Pollisco-Botengan MA (1997) CPPAP Monitoring and Evaluation (M&E) Framework. DENR and NIPA, Inc., Manila

Pollisco W, Danielsen F, Nozawa C, Jensen A and Balete D (1997) Proceedings of Workshop on Monitoring Biodiversity in Protected Areas of the Philippines. SYLVATROP The Technical Journal of Philippine Ecosystems and Natural Resources 7: 101–104

Saberwal VK and Kothari A (1996) The human dimension in conservation biology curricula in developing countries. Conservation Biology 10: 1328–1331

Schaik CP van, Terborgh T and Dugelby B (1997) The silent crisis: the state of rain forest nature preserves. In: Kramer R, Schaik CP van and Johnson J (eds) Last Stand: Protected Areas & the Defense of Tropical Biodiversity. Oxford University Press, New York

Simberloff D (1998) Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? Biological Conservation 83: 247–257

Thompson WL, White GC and Gowan C (1998) Monitoring Vertebrate Populations. Academic Press, San Diego

Vora RS (1997) Developing programs to monitor ecosystem health and effectiveness of management practices on Lakes States National Forests, USA. Biological Conservation 80: 289–302

Wangwacharakul V, Claridge G and Mather R (1996) Biodiversity Monitoring and Evaluation in the Lao PDR: Developing a Protected Area Approach. MIDAS Agronomics Co. Ltd., Bangkok

Weber FR (1990) Preliminary Indicators for Monitoring Changes in the Natural Resource Base. A.I.D. Program Design Evaluation Methodology No. 14. USAID, Washington, DC

Wells MP (1998) Institutions and incentives for biodiversity conservation. Biodiversity and Conservation 7: 815–835

Wilson JG (1994) The Role of Bio-indicators in Estuarine Management. Estuaries 17: 94–101

Wilson DE, Cole FR, Nichols JD, Rudran R and Foster MS (eds) (1996) Measuring and Monitoring Biological Diversity. Standard Methods for Mammals. Smithsonian Institution Press, Washington and London

World Bank (1992) Guidelines for Monitoring and Evaluation of GEF Biodiversity Projects. The World Bank, Washington

World Bank (1998) Guidelines for Monitoring and Evaluation for Biodiversity Projects. Environment Department Note No. 65. The World Bank, Washington

WRI, UNEP, UNDP and WB (1998) World Resources 1998–99, pp 320–321. Oxford University Press, New York, Oxford

APPENDIX II

Danielsen, F., Mendoza, M.M., Alviola, P., Balete, D.S., Enghoff, M., Poulsen, M.K. and Jensen, A.E. 2003.
Biodiversity monitoring in developing countries: what are we trying to achieve?
Oryx 37: 407–409.

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Forum

Biodiversity monitoring in developing countries: what are we trying to achieve?

Finn Danielsen, Marlynn M. Mendoza, Phillip Alviola, Danilo S. Balete, Martin Enghoff, Michael K. Poulsen and Arne E. Jensen

In a stimulating review of biodiversity monitoring programmes, Yoccoz *et al*. (2001) recently concluded that many existing programmes suffer from two major design deficiencies: a lack of well-articulated objectives, and a neglect of different sources of error in the estimation of biological diversity. The paper was primarily devoted to the sources of data uncertainty. While we agree with the conclusion that substantial thought should be given to the question of design, and to 'how', 'what' and 'why' to monitor, it is worth considering what we want to achieve by monitoring and, considering the socio-economic context, what is practically feasible. Design deficiencies that apply in developed countries may be irrelevant in some developing countries where the *de facto* day-to-day management of biological resources is largely in the hands of poor rural people (Getz *et al*., 1999), and local authorities have virtually no operational funding.

Our main aim here is to highlight the fact that, in many parts of the world, the context is different from the baseline of Yoccoz *et al*. (2001). More importantly (and not discussed by Yoccoz *et al*., who primarily reviewed initiatives in the USA), most biodiversity monitoring programmes in less wealthy countries suffer from being unrealistically large, complicated and impossible to sustain with the locally available funds and human resources (Danida, 2000). Many programmes collapse almost immediately when the donor funding stops because they are designed at a cost-level that will never be sustained. In addition, most programmes are unable to contribute to biodiversity conservation because they are ineffective in integrating information into decision-making. These constraints are particularly acute at a time when there is an urgent need to increase the effectiveness of conservation efforts in the tropics (Achard *et al*., 2002).

One could argue that these constraints are unrelated to biodiversity monitoring and should be addressed by strengthening the government institutions responsible and providing additional training and funds (Bawa & Menon, 1997). However, whether we like it or not, we are not likely to see significantly improved environmental departments in developing countries for some time. By neglecting these constraints and emphasizing the need for more standardized approaches, the recommendations of Yoccoz *et al*. (2001) may lead to repeated attempts to develop unrealistic programmes that only divert scarce funds from fundamental management priorities (e.g. Sheil, 2001). It is time to recognize the inherent tensions between data standardization, facility of collection and ease of making contributions to management. What really matters for management-oriented biodiversity monitoring in developing countries is that methods are very simple, cost-effective and possible to sustain with limited external support, and that the time from data sampling to management action is short (Danida, 2000). Recent advances in combining scientific and participatory methods may provide a solution (Margoluis & Salafsky, 1998; World Bank, 1998; Danielsen *et al*., 2000; ETFRN, 2002).

In the Philippines at least 156 management actions have been undertaken in eight protected areas over 2½ years on the basis of integrated scientific and participatory monitoring methods (Nordeco & DENR, 2002). In relation to the hunting of wildlife, actions included: the development of bylaws at tribal (*lapat*), village and municipal level, seasonal closures for hunting, banning of certain destructive hunting methods, the establishment of a system of fines for leaving snares unattended, awareness-raising about needs for hunting regulations among local people, strengthened enforcement of hunting regulations in certain areas, and pilot-testing of more sustainable hunting practices.

Similar initiatives that combine methods from the natural and social sciences have been developed in Laos (Ling, 2000; Steinmetz, 2000), Yunnan in China (Rijsoort & Jinfeng, 2002) and Tanzania (Danida, 2003).

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Received 6 August 2002. Revision requested 4 March 2003. Accepted 18 June 2003.

Examples of methods are provided in Table 1. An added advantage, beyond the simplicity and low cost, is that the meaning of the monitoring can be grasped by local people who are in practice the custodians of the areas. In fact the methods are focused on authorities supporting local people in enhancement and formalization of the existing, informal monitoring already carried out.

Central to the success of integrated assessment methods in these initiatives are: (i) that representatives of local communities are involved in developing the local application of the methods, (ii) that already existing community-based monitoring systems are recognized and built upon, (iii) that focus is at the field/village level where management decisions are taken, (iv) that monitoring activities are kept simple and fitted into the day-to-day work of the local people, (v) that government staff are involved, and (vi) that there is mutual trust between local communities and government staff.

The strength of this approach does not lie in detecting trends with a statistically acceptable degree of confidence or in contributing to international publishing. It lies instead in proven efficiency, even in the short-term, in strengthening local management of the land and resources and dealing with threats to biodiversity (ETFRN, 2002; Nordeco & DENR, 2002). Moreover, it makes local stakeholders more motivated to agree on and participate in law enforcement, resource use regulation and reaction to encroachment by outsiders, increasing the likelihood of successful management. In addition, this approach improves communication between local stakeholders and authorities, increases transparency of decision-making and strengthens community-based resource management systems.

How general are these considerations? It seems that integrating scientific and participatory biodiversity monitoring techniques have particular potential in areas where (i) authorities embark on shared management of resources with local people, and authorities and locals have common interest in the management objectives, (ii) rural people depend on the use of natural resources and have a relative strong societal coherence and long history of settlement, and (iii) the resources are not so valuable that they attract powerful outsiders against whom local people have no defence (Danielsen *et al.*, 2000; ETFRN, 2002). While this approach has thus far been used primarily in protected areas, it is likely to be equally effective in other places where the appropriate authorities have interests and staff.

The main drawback of this approach is that we do not yet know the extent to which the method is able to detect true trends. By its very nature, the integrated approach does not include all of the desirable elements to ensure that monitoring programs provide unequivocal answers (Margules *et al.*, 1998). In-depth monitoring of selected habitats and species are also vital. Most programmes integrating scientific and participatory biodiversity monitoring methods in developing countries are relatively young and untested. Although cost-effective, it remains to be seen whether they will be sustained in the long term. A key determinant is whether conservation professionals and scientists will accept that this approach has potential for improving resource management.

Many countries are moving towards decentralization of natural resource management. International policy agreements emphasize the need for increased public participation in environmental decision-making (e.g. the Aarhus Convention of 1998 (UNECE, 1998) on access to information, public participation in decision-making, and access to justice in environmental matters). Integrating participatory methods into biodiversity assessment can be a powerful tool for implementing these policies.

Countries party to the Convention on Biological Diversity are obliged to monitor biodiversity (Article 7.b) but many have yet to establish monitoring programmes (Global Forest Coalition/FERN, 2002). If significant financial support for monitoring is to be provided by

Table 1 Examples of field methods for monitoring biodiversity and resource use.

Type of method	Field method	Source
Conventional scientific methods	Permanent forest inventory plots	Alder & Synnott, 1992
	Territory mapping of birds	Bibby *et al.*, 2000
	Arthropod protocols	Coddington *et al.*, 1991
	Quantitative socio-economic survey with statistical analysis	Marsh, 1999
Integrated scientific and participatory methods	Focus group discussions between protected area staff and local volunteer members of 'community monitoring groups'	Danielsen *et al.*, 2000
	Routine observation of wildlife and resource use during regular patrols	Danielsen *et al.*, 2000
	Recording by community members of observations of key species and visits of outsiders in a village logbook	Steinmetz, 2000 Ling, 2000

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governments and development agencies it will be essential that the programmes make a real contribution to arresting the root causes of extinction. Otherwise, biodiversity monitoring programmes in developing countries are likely to remain no more than isolated academic exercises.

References

Achard, F., Eva, H.D., Stibig, H.-J., Mayaux, P., Gallego, J., Richards, T. & Malingreau, J.-P. (2002) Determination of Deforestation Rates of the World's Humid Tropical Forests. *Science*, **297,** 999–1002.

Alder, D. & Synnott, T.J. (1992) Permanent sample plot techniques for mixed tropical forest. *Tropical Forestry Papers*, **25**.

Bawa, K.S. & Menon, S. (1997) Biodiversity monitoring: the missing ingredients. *Trends in Ecology & Evolution*, **12,** 42.

Bibby, C.J., Burgess, N.D. & Hill, D.A. (2000) *Bird Census Techniques*. Academic Press, London, UK.

Coddington, J.A., Griswold, C.E., Dávila, D.S., Peñaranda, E. & Larcher, S.F. (1991) Designing and testing sampling protocols to estimate biodiversity in tropical ecosystems. In *The Unity of Evolutionary Biology: Proceedings of the Fourth International Congress of Systematic and Evolutionary Biology* (ed. E.C. Dudley), pp. 44–60. Dioscorides Press, Portland, USA.

Danida (2000) *Towards 'Best' Practice in Biodiversity Conservation in Southern Africa.* Royal Danish Ministry of Foreign Affairs, Copenhagen, Denmark.

Danida (2003) *Development of Biodiversity Monitoring for Udzungwa Mountains Forest Management and Biodiversity Conservation Project and Community Based Natural Woodlands Management Project (MEMA). Final Report.* Royal Danish Ministry of Foreign Affairs, Copenhagen, Denmark.

Danielsen, F., Balete, D.S., Poulsen, M.K., Enghoff, M., Nozawa, C.M. & Jensen, A.E. (2000) A simple system for monitoring biodiversity in protected areas of a developing country. *Biodiversity and Conservation*, **9,** 1671–1705.

European Tropical Forest Research Network (ETFRN) (2002) *Participatory Monitoring and Evaluation of Biodiversity: Internet Workshop and Policy Seminar.* Environmental Change Institute, University of Oxford, Oxford, UK [http://www.etfrn.org/etfrn/workshop/biodiversity/index.html, accessed 23 July 2003].

Getz, W.M., Fortmann, L., Cumming, D., du Toit, J., Hilty, J., Martin, R., Murphree, M., Owen-Smith, N., Starfield, A.M. & Westphal, M.I. (1999) Sustaining Natural and Human Capital: Villagers and Scientists. *Science*, **283,** 1855–1856.

Global Forest Coalition/FERN (2002) *Status of Implementation of Forest-Related Clauses in the CBD: An Independent Review & Recommendations for Action.* Global Forest Coalition [http://www.fern.org/pubs/reports/cbd/finalcbd.pdf, accessed 23 July 2003].

Ling, S. (2000) *NBCA Biodiversity Monitoring. Part One: Monitoring Manual. Part Two: Trainers Notes.* Forest Management and Conservation Programme, Lao-Finnish-World Bank-GEF Cooperation, Vientiane, Lao PDR.

Margoluis, R. & Salafsky, N. (1998) *Measures of Success: A Systematic Approach to Designing, Managing and Monitoring Community-Oriented Conservation Projects.* Biodiversity Support Program Adaptive Management Series, Washington, DC, USA.

Margules, C.R., Austin, M.P., Davies, K.F., Meyers, J.A. & Nicholls, A.O. (1998) The design of programs to monitor forest biodiversity: lessons from the Wog Wog habitat fragmentation experiment. In *Forest Biodiversity Research, Monitoring and Modelling: Conceptual Background and Old World Case Studies* (eds. F. Dallmeier & J.A. Comiskey), pp. 183-196. Parthenon Publishing, Paris, France.

Marsh, I. (ed.) (1999) *Sociology: Dealing with Data*. Longman, Essex, UK.

Nordeco & DENR (2002) *DENR Biodiversity Monitoring System. Implementation Results from Eight Protected Areas January 1999–June 2001, The Philippines.* Department of Environment and Natural Resources, Manila, prepared for the World Bank.

Rijsoort, J. van & Jinfeng, Z. (2002) *Development of Participatory Resources Monitoring in Two Nature Reserves in Yunnan, P.R. China* [http://www.etfrn.org/etfrn/workshop/biodiversity/index.html, accessed 23 July 2003].

Sheil, D. (2001) Conservation and biodiversity monitoring in the tropics: realities, priorities and distractions. *Conservation Biology*, **15,** 1179–1182.

Steinmetz, R. (2000) *Ecological Surveys, Monitoring and the Involvement of Local People in Protected Areas of Lao PDR.* IIED Evaluating Eden Series, IIED, London, UK.

United Nations Economic Commission for Europe (UNECE), Environment and Human Settlements Division (1998) *Aarhus Convention (Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters), adopted 25 June 1998* [http://www.unece.org/env/pp, accessed 23 July 2003].

World Bank (1998) *Guidelines for Monitoring and Evaluation for Biodiversity Projects.* Environment Department Note No. 65, the World Bank, Washington, DC, USA.

Yoccoz, N.G., Nichols, J.D. & Boulinier, T. (2001) Monitoring of biological diversity in space and time. *Trends in Ecology & Evolution*, **16,** 446–453.

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APPENDIX III

Danielsen, F., Mendoza, M.M., Tagtag, A., Alviola, P., Balete, D.S., Enghoff, M., Poulsen, M.K. and Jensen, A.E. 2003.
On participatory biodiversity monitoring and its applicability – a reply to Yoccoz *et al.* and Rodríguez.
Oryx 37: 412.

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Forum

On participatory biodiversity monitoring and its applicability – a reply to Yoccoz *et al.* and Rodríguez

Finn Danielsen, Marlynn M. Mendoza, Anson Tagtag, Phillip Alviola, Danilo S. Balete, Martin Enghoff, Michael K. Poulsen and Arne E. Jensen

Rodríguez (2003) and Yoccoz *et al.* (2003) acknowledge our evidence that integrated scientific and participatory methods for monitoring biodiversity are effective in strengthening management of land and resources (Danielsen *et al.*, 2003) but Rodríguez questions whether this approach is replicable outside the Philippines. Locally-based biodiversity monitoring systems involving non-scientists in assessments have been established, and are already leading to conservation actions in terrestrial, marine and freshwater ecosystems in at least 10 other developing countries on all three tropical continents (data set available from the authors; see also a forthcoming special issue of *Biodiversity and Conservation*).

This is not surprising as most developing countries fulfil the key criteria for where this approach should have the strongest potential. In the majority of developing countries the sharing of the management of protected areas with local communities, or at least community participation in resource management, forms a part of official government policy. In most of these countries, rural people live inside or adjacent to some of the protected areas and depend on forest and wetland products from those areas (e.g. Saberwal & Kothari, 1996). In addition, chronic underfunding of protected areas seems to be the rule rather than the exception (James *et al.*, 1999).

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Accepted 21 July 2003.

From one country to another there will be differences, such as in terms of the management objectives for protected areas and the relevant species and resource uses to be monitored. Integrated scientific and participatory monitoring methods must be tailored to the specific local, social and ecological context. It is unlikely that there is a 'one size fits all' solution.

We concur with Rodríguez (2003) on the great need for more research, but a lack of information should not prevent us from using the available information to take action and from making meaningful use of already existing human resources. Although we agree that integrated scientific and participatory methods for monitoring biodiversity need to be supplemented by in-depth monitoring of selected habitats and species, we maintain that our findings in the Philippines reveal a fundamentally important and globally applicable, simple and cost-effective approach for improving management of biodiversity in developing countries.

References

Danielsen, F., Mendoza, M.M., Alviola, P., Balete, D.S., Enghoff, M., Poulsen, M.K. & Jensen, A.E. (2003) Biodiversity monitoring in developing countries: what are we trying to achieve? *Oryx*, **37**, 407–409.

James, A.N., Green, M.J.B. & Paine, J.R. (1999) *Global Review of Protected Area Budgets and Staff*. World Conservation Monitoring Centre, Cambridge, UK.

Rodríguez, J.P. (2003) Challenges and opportunities for surveying and monitoring tropical biodiversity – a response to Danielsen *et al.* *Oryx*, **37**, 411.

Saberwal, V.K. & Kothari, A. (1996) The human dimension in conservation biology curricula in developing countries. *Conservation Biology*, **10**, 1328–1331.

Yoccoz, N.G., Nichols, J.D. & Boulinier, T. (2003) Monitoring of biological diversity—a response to Danielsen *et al.* *Oryx*, **37**, 410.

© 2003 FFI, *Oryx*, **37**(4), 412 DOI: 10.1017/S0030605303000760 Printed in the United Kingdom

APPENDIX IV

Danielsen, F., Burgess, N.D. and Balmford, A. 2005.
Monitoring matters: examining the potential of locally-based approaches.
Biodiversity and Conservation 14: 2507–2542.

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Biodiversity and Conservation (2005) 14:2507–2542
DOI 10.1007/s10531-005-8375-0
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Guest Editorial

Monitoring matters: examining the potential of locally-based approaches

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Received 29 October 2004; accepted in revised form 5 November 2004

Key words: 2010 target, Accuracy, Biodiversity monitoring, Citizen science, Community-based monitoring, Community-based natural resource management, Conservation costs, Conservation impact, Decision-making, Local constituencies, Locally-based monitoring, Participatory monitoring, Ranger-based monitoring, Sustainability, Volunteer-based monitoring

Abstract. Monitoring of biodiversity and resource use by professional scientists is often costly and hard to sustain, especially in developing countries, where financial resources are limited. Moreover, such monitoring can be logistically and technically difficult and is often perceived to be irrelevant by resource managers and the local communities. Alternatives are emerging, carried out at a local scale and by individuals with little formal education. The methods adopted span a spectrum, from participatory monitoring where aims and objectives are defined by the community, to ranger-based monitoring in protected areas. What distinguishes these approaches is that local people or local government staff are directly involved in data collection and (in most instances) analysis. In this issue of Biodiversity and Conservation, 15 case studies examine whether these new approaches can address the limitations of professional monitoring in developing countries. The case studies evaluate ongoing locally-based monitoring schemes involving more than 1500 community members in 13 countries. The papers are based on a symposium held in Denmark in April 2004 (www.monitoringmatters.org). Here, we review how the case studies shed light on the following key issues concerning locally-based methods: cost, sustainability, their ability to detect true local or larger-scale trends, their links to management decisions and action, and the empowerment of local constituencies. Locally-based monitoring appears to be consistently cheap relative to the costs of management and of professional monitoring, even though the start-up costs can be high. Most local monitoring schemes are still young and thus their chances of being sustained over the longer term are not yet certain. However, we believe their chances of surviving are better than many professional schemes, particularly when they are institutionalised within existing management structures, and linked to the delivery of ecosystem goods or services to local communities. When properly designed, local schemes yield locally relevant results that can be as reliable as those derived from professional monitoring. Many management decisions emanate from local schemes. The decisions appear to be taken promptly, in response to immediate threats to the environment, and often lead to community-based actions to protect habitats, species or the local flow of ecosystem benefits; however, few local schemes have so far led to actions beyond the local scale. Locally-based monitoring schemes often reinforce existing community-based resource management systems and lead to change in the attitude of locals towards more environmentally sustainable resource

management. Locally-derived data have considerable unexplored potential to elucidate global patterns of change in the status of populations and habitats, the services they provide, and the threats they face, but more effort is needed to develop effective modalities for feeding locally-derived data up to national and international levels.

Introduction

Why does monitoring matter?

The title of this special issue asserts that monitoring wild nature and the benefits which it bestows on people matters, but to whom and why? Recent developments suggest at least three kinds of actors and actions for which such monitoring is becoming increasingly important.

At the international, regional, and national scales a raft of macro-policy initiatives have committed governments to achieving quantitative targets in conserving biodiversity and ensuring its benefits are distributed equitably. At the 2002 Johannesburg World Summit on Sustainable Development, for example, representatives of 190 countries committed themselves to the Convention on Biological Diversity's target of 'achieving by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional, and national level…' (UNEP 2002). Related commitments by European Union member states are more ambitious, requiring 'that biodiversity decline should be halted… by 2010' (European Council 2001). Achieving sustainable use of natural resources is also key to meeting the United Nations' Millenium Development Goals (United Nations 2000). Yet, important though these high-level goals are, policy-makers simply will not know whether the goals are being met without robust and representative systems for monitoring the changing state of nature (Jenkins et al. 2003; Balmford et al. 2005).

Likewise, monitoring is crucial at all scales for conservationists to assess the impact of their interventions. Identifying the circumstances under which different kinds of interventions succeed (or indeed fail) requires effective monitoring of managed and control areas, or of managed areas both before and after an intervention. Ways of measuring the effectiveness of different projects and programmes are also increasingly required by the institutions and individuals that fund conservation agencies and Non-Governmental Organisations (NGOs), in particular when faced with problems of measuring the impact of past project interventions (e.g. Kremen et al. 1994). Filling-in of scorecards can be very useful for rapidly assessing the urgency and intensity of threats (Margoluis and Salafsky 2001) and for examining the management effectiveness of protected areas (Stolton et al. 2003) but they provide no information on biodiversity. Growing awareness of the need for monitoring data to evaluate the impact of conservation activities is reflected in the growth of so-called evidence-based conservation (Sutherland et al. 2004), as well as the recent establishment of dedicated consortia such as the Conservation Measures

Partnership (www.conservationmeasures.org/CMP/) and the Cambridge Conservation Forum's Harmonising Measures of Success project (www.cambridgeconservationforum.org/macarthur.html).

Last, and crucially, the past two decades have seen a progressive shift towards involving local communities formally and more effectively in the management of protected areas, and encouraging them to manage their own lands in ways that are compatible with agreed conservation goals (Brandon and Wells 1992; Caldecott 1998; Hulme and Murphree 1999; Dubios and Lowore 2000; Roe and Jack 2001; Jeanrenaud 2002a, b; Wells and McShane 2004; Sheil and Lawrence 2004). These newly recognised partners in conservation also require monitoring data to inform their decisions – in a form that is accessible and credible to them, and which measures those aspects of biodiversity that are of greatest local relevance.

The need for monitoring is thus clear, but who should carry it out? To date, most attention has been paid to what we here term 'professional monitoring', by trained scientists working primarily for government agencies or NGOs. Why should we be interested in looking further afield?

Challenges to professional monitoring

Professional monitoring programmes face a number of important challenges, especially in developing countries, where financial and human resources are especially limited:

1. Professional monitoring is often costly, at least relative to the budgets of most conservation agencies. Employing scientists with appropriate field and analytical skills, buying and maintaining field equipment, and running data analysis facilities, can together take up a significant fraction of an organisation's resources, without directly delivering conservation on the ground.
2. High cost in turn means that many monitoring programmes are not sustained over time. The resulting work may still be valuable as a series of one-off assessments, but it does not constitute monitoring, and it cannot provide the information on trends over time essential to the kinds of management decisions described above.
3. Professional monitoring can often be difficult, both logistically, technically, and analytically. To some extent these problems can be addressed through explicit advance consideration of the importance of systematic, unbiased and sufficiently replicated data collection. However, some aspects of biodiversity remain technically difficult to monitor – such as the extent or condition of certain habitat types which cannot be readily measured via remote sensing, and the rate of delivery of certain ecosystem services. As a consequence, only a minority of the world's major biomes, and very few key ecosystem services, are currently being monitored at a regional or global scale (Balmford et al. 2003b; Jenkins et al. 2003).

4. Monitoring is frequently perceived to be insufficiently relevant to the needs of managers (e.g. Sheil 2001), and as a consequence, may have limited bearing on management decisions. The solution to this is to involve managers, right from the outset, in identifying the objectives of the monitoring programme, and in checking, at an early stage, that these objectives are being met (Yoccoz et al. 2001; Royal Society 2003; Green et al. 2005). However, this is an increasingly difficult challenge for professional monitoring in a world where formal responsibilities for resource management are becoming devolved away from high-level government employees.
5. A related issue is that professional monitoring is often seen as paying inadequate attention to the objectives of other key stakeholders, besides professional resource managers – especially local communities whose livelihoods are often closely impacted by the resources concerned (Steinmetz 2000; Lawrence and Elphick 2002). Again, in principle, professional monitoring can and should address this, through extensive dialogue with all stakeholders at the onset and throughout the course of monitoring but in reality, shortages of money, time, and trained personnel can make this a tall order.

In the light of these challenges, a suite of alternative, locally-based approaches to monitoring have begun to emerge; these form the focus of this special issue.

Locally-based monitoring

We use the term 'locally-based monitoring' to embrace a broad range of approaches, from self-monitoring of harvests by local resource users themselves, to censuses by local rangers, and inventories by amateur naturalists; we include techniques labelled as 'participatory monitoring', 'community-based monitoring', 'hunter self-monitoring' and 'ranger-based monitoring'. Many of these approaches are directly linked to resource management, but the entities being monitored vary widely, from individual animals and plants, through habitats, to ecosystem goods and services. However, all of the approaches have in common that the monitoring is carried out at a local scale by individuals with little formal education, and that local people or local government staff are directly involved in data collection and (in most instances) analysis.

It has been suggested that such locally-based approaches have considerable potential to complement professional monitoring in developing countries by addressing some of the shortfalls we have just encountered (Danielsen et al. 2000). Specifically, it should be possible to carry out locally-based monitoring at much less cost than professional monitoring, and hence for it to be more sustainable. Through careful training and sampling design, it should be possible for locally-based monitoring to yield results which are as reliable as those

of professional techniques (Yoccoz et al. 2003), and which can shed light on some aspects of biodiversity which are hard to monitor professionally. Perhaps most importantly, locally-based monitoring will by its nature tend to focus on management issues of greatest concern to stakeholders, and is thereby likely to have considerable advantage over professional approaches in its potential to influence on-the-ground management activities, and to empower and enhance capacity among local stakeholders.

Yet promising though these suggestions are, they now need testing (Danielsen et al. 2003a, b; Rodríguez 2003). How far has the potential of locally-based monitoring translated into tangible results on the ground in developing countries?

This issue

To address this question, the Nordic Agency for Development and Ecology (NORDECO, Denmark), and the Zoology Department of Cambridge University (UK) hosted a two-day symposium on locally-based monitoring in Denmark in April 2004. The symposium included 14 case studies, which form the backbone (together with an additional paper solicited since the meeting) of this special issue. In this introductory paper we begin by outlining the range of the case studies, and then review how they shed light on each of the issues raised above – the cost of locally-based monitoring; prospects for its being sustainable; its ability to generate accurate and precise data; linkages with management decisions and action; and its ability to empower local communities. We then briefly consider ways in which locally-derived data might be used to plug larger-scale monitoring gaps, before closing with a brief set of recommendations for the future.

Case studies

This special issue presents results from case studies spanning a range of continents, biomes, land tenure systems, and stakeholders. The examples also vary widely in terms of what is monitored, over what area, and at what frequency and cost (Table 1). Thirteen studies outline ongoing monitoring schemes, while one (Roberts et al. 2005) describes a planned scheme and one (Hockley et al. 2005) models general constraints on locally-based monitoring. These papers were derived from a set of more than 30 potential case studies that were proposed to the symposium organisers, and were chosen to reflect the widest possible set of situations and issues.

We have assessed the various methods used in the different symposium papers, together with a review of the relevant literature, and on this basis propose five generic methods that are suitable for locally-based biodiversity monitoring in developing countries (Table 2).

Table 1. Case studies of ongoing locally-based monitoring schemes.

Case study[a]	Country	Biome[b]	Land tenure system[c]	Type of participation by community members[d]	Who compiles data[e]	What is monitored[f]	Spatial scale. Total size of area monitored[g] (ha)	Interval between successive bouts of data collection (days)	Community member time spent on data collection (person-hours/ha/yr)	Payment provided to community members involved in the monitoring (USD)	Indicative recurrent costs of monitoring[h] (USD/ha/yr)	Indicative total funding for management (USD/ha/yr)
van Rijsoort and Jinfeng 2005	China	t	PA	I (48)	R/C	Use/Wildl	46,725 (2)	Varies	No data	Small allowance and/or free seedlings for a nursery	No data	4.87 (2000)
Bennun et al. 2005	Kenya	t	Non-PA	I (100)	C	Use/Wildl	77,000 (1)	180	0.005	0 (meals)	0.01 (2003)	50
Poulsen and Luanglath 2005	Laos	t (fw)	PA	I (30)	R/C	Use/Wildl	240,000 (1)	Varies	0.008	0 (meals)	0.02 (2002)	0.02
Stuart-Hill et al. 2005	Namibia	t (fw)	C-PA	I (200)	C	Use/Wildl	7,000,000[i] (30)	Varies	0.005[i]	100/mth[j]	0.01[i, j] (2003)	0.05–0.65[i]
Danielsen et al. 2005	Philip-pines	t (m, fw)	PA	I (350)	R/C	Use/Wildl	1,090,000 (8)	90	0.005	0 (snacks)	0.04 (2001)	1.75
Topp-Jørgensen et al. 2005	Tanzania	t	PA/non-PA	I (298)	C	Use/Wildl	144,403 (4)	Varies	0.201	0–2/day	0.05[k] (2003)	0.23
Noss et al. 2005	Bolivia	t	C-PA	II (125)	C	Hunting	400,000 (1)	1–7	0.009	Hunters: 0 Recorders: 150/month	0.13 (2003)	1.63
Becker et al. 2005	Ecuador	t	C-PA	II (10)	C/V	Birds	2,430 (1)	360	1.77	5–10/day	2.50 (2003)	2.88
Brashares and Sam 2005	Ghana	t	PA	III (0)	R	Use/Wildl	516,500 (2)	30	No community members involved[l]	No community members involved	0.06 (2003)	0.18[m]

Gray and Kalpers 2005	Uganda, Rwanda, DRC	t	PA	III (0)	R	Use/Wildl	78,600 (3)	Varies	No community members involved	No community members involved	1.26 (2003)	36.1[n]
Townsend et al. 2005	Ecuador	fw	C-PA	I (150)	C	River turtles	1,200[o] (1) along river	10–14[p]	9.92	Nest reporters: 0.25/nestThose who census the river by canoe: 100/month	10.0 (2003)	No data
Andrianandrasana et al. 2005	Mada-gascar	fw	Non-PA	II (155)	C	Use/Wildl	42,810 (1)	360	0.065	2/day (+prizes)	0.09 (2002)	0.14[q]
Uychiaoco et al. 2005	Philip-pines	m	PA/non-PA	II (54)	C	Use/Wildl	74,885 (9)	180	28.8	0 (meals)	14.0 (2003)	30

[a] Source of information (this special issue, and correspondence with the authors).
[b] t = terrestrial; fw = freshwater; m = marine (bracketed biomes account for a minor portion of the area under monitoring).
[c] C-PA = protected area managed by the local communities; non-PA = outside of protected area; PA = protected area under government authority.
[d] I = Monitoring scheme intended to involve the community members in the local design of the monitoring as well as in data collection, data analysis, and monitoring-based decision-making; II = Monitoring scheme intended to involve the community members mainly in data collection and monitoring-based decision-making; III = Monitoring scheme not currently intended to involve community members. The number of community members directly involved in the monitoring is indicated in brackets.
[e] C = community members; R = government rangers; V = volunteers (from abroad).
[f] Use = resource use; Wildl = wildlife (species/populations and habitats).
[g] The number of areas monitored is indicated in brackets.
[h] Year in brackets; excluding depreciation of equipment.
[i] Many conservancies are located in large deserts.
[j] Funds generated locally from trophy hunting or tourism.
[k] Funds generated locally from user fees.
[l] The rangers however often come from local communities.
[m] This figure includes the costs of monitoring.
[n] Data from Uganda (Mgahinga Gorilla National Park) and Rwanda (Parc National des Volcans) only.
[o] The Cofán-managed territory of 120,000 ha benefit from this monitoring.
[p] River census.
[q] Excluding salaries and competition prizes.

Table 2. Five non-exclusive generic methods suitable for locally-based monitoring of biodiversity in developing countries.

Method	Habitat coverage	Equipment	Pros	Cons	Remarks	Case studies using method
1. Patrol records. Filling-out routine patrol sheets on key species, habitats, or extent of resource exploitation (incl. GPS recordings of infringements; ranger event books)	Useful both on land and in water	Notebook, pen, identification guide[a] and binoculars	Easy to integrate in labour schedule of rangers. Simple and easy to grasp even for people without training. Encourages rangers to be observant of changes; and increases the motivation for their work. Powerful at generating management interventions to protect species and natural habitats	Will produce biased results if the patrolling are localised, or if patrol routes sample different habitats unrepresentatively; both problems are likely	Some effort correction possible, if data is confined to specified locations and a constant number of informants, or patrol coverage is measured by use of toponyms/GPS	Brashares and Sam 2005; Danielsen et al. 2005; Gray and Kalpers 2005; Poulsen and Luanglath 2005; Stuart-Hill et al. 2005; Topp-Jørgensen et al. 2005
2. Transects. Simple dedicated transects of wildlife and human resource use (incl. reef fish visual census and manta tow estimates of hard coral and sand cover; canoe transects of river turtles)	Useful both on land (transect walk) and in water (transect cruise/swim)	Notebook, pen, identification guide, binoculars, watch, water container with water, food (mask/fins for transect swim)	Minimal training of data collectors needed. Corrected for effort.Relatively easy interpretation. Data also useful for tracking large-scale vertebrate population trends (see Fig. 1)	Data collectors need species identification skills. The transects should be censused by the same person every time. Biased by seasonal changes in detectability of wildlife. In freshwater wetlands, access to permanent routes may be constrained by water dynamics, invasive plants etc.	Careful selection of transect routes is critical	Andrianandrasana et al. 2005; Becker et al. 2005; Danielsen et al. 2005; Townsend et al. 2005; Uychiaoco et al. 2005
3. Species lists. Presence/ absence of species on fixed-time lists (incl. 1-day index of abundance)	Useful both on land and in water	Notebook, pen, identification guide, binoculars	Capture *ad hoc* sightings routinely gathered by e.g. birdwatchers	Lists perhaps biased towards rare species. Observers might be attracted to the more desirable places for recording species. In addition, variation of effort is a source of bias (see Roberts et al. 2005).	The usefulness of this method for generating conservation management interventions has not yet been assessed	Bennun et al. 2005; Hockley et al. 2005; Roberts et al. 2005

4. Simple photography. On-the-ground fixed point photography	Useful both on land and above water in wetlands. Particularly useful in undulating terrain and along curved coastlines	Notebook, pen, camera (Single Lens Reflex) with battery, films, compass, and, if possible, a tripod. A topographic map, a GPS, and paint for marking the site permanently would also be useful	Minimal training of data collectors needed. Data-set is objective, independent of observer and identification skills and of permanent value. Useful for generating convincing inputs to local level awareness-raising and education work	Data collectors need camera operation skills	Careful selection of sites is critical. Sites should be easily accessible, from where one can see the surrounding landscape	Bennun et al. 2005; Danielsen et al. 2005; van Rijsoort and Jinfeng 2005
5. Village group discussions. Discussions between government staff and local volunteer members of 'community monitoring groups' (incl. hunter self-monitoring; interviews; village log books; fish/ shellfish capture recording)	Useful in both land and water habitats	Large sheets of paper, markers, identification guide, food	Relatively easy interpretation. Provides an opportunity for villagers and authorities to discuss management. Powerful at generating local bylaws, joint government/ community actions, and actions to ensure local flow of ecosystem benefits (Danielsen et al. 2005)	Data is qualitative. Information is not objective. People may be reluctant to provide information on resource use as they fear restrictions. Ineffective in areas with poor relationship between the authorities and the local people	The information is based on local communities' own perceptions of trends. Data gathered continuously from a number of representative communities can however provide a valid picture of general trends	Andrianandrasana et al. 2005; Danielsen et al. 2005; Noss et al. 2005; Poulsen and Luanglath 2005; Topp-Jørgensen et al. 2005; Townsend et al. 2005; Uychiaoco et al. 2005; van Rijsoort and Jinfeng 2005

(a) For a review of the usefulness of identification guides for environmental management, see World Bank 1996.

Patrol records

The first of these methods involves filling-out sheets with observations and records provided by local people on key species, habitats, or the extent of resource use during patrols. This method provides quantitative data on changes in abundance of species or the extent of threats to habitats. It has been adapted for use in both protected areas by employed rangers (e.g. Brashares and Sam 2005; Gray and Kalpers 2005 (this issue)) and also within village-based monitoring systems where the participants are either volunteers or members of environmental committees involved with the management of the resource (e.g. Stuart-Hill et al. 2005; Topp-Jørgensen et al. 2005 (this issue)). So long as the methodology and the forms used are simple enough then the method can be sustained at village level, but temptations to make the recording methodology more complex – for example by changing from simple school exercise books that are available at village level, to photocopied forms that cannot be reproduced locally – are often hard to resist.

Transects

The second set of methods uses simple dedicated transects of wildlife and human resource use to collect quantitative data on changes over time. The method has been adapted to work in a variety of habitats, from forests through grasslands to coral reefs and rivers (e.g. Obura et al. 2002; Gaidet et al. 2003 and papers by Townsend et al. 2005 and Uychiaoco et al. 2005 (this issue)). The locally-based transect method can be undertaken on foot, in canoes along rivers or while swimming over coral reefs. As with the patrol method, the key to embedding the method at local level is to make it as simple as possible.

Species lists

The third set of these methods is a way to measure abundance changes in wildlife species, and involves an assessment of the presence/absence of species on lists summarising all the species encountered during a defined period of time in the field such as a day or an hour (Roberts et al. 2005 (this issue)). If enough lists are compiled then the proportion of times that a particular species is recorded can be used as proxy measure of abundance (e.g. Pomeroy 1992; Bibby et al. 2000). This method is somewhat more technically demanding than the others, but has been used successfully in two of the present case studies (Bennun et al. 2005; Hockley et al. 2005 (this issue)).

Photography

The fourth type of method consists of simple fixed-point photography from a suitable vantage point on the ground. Human memory can be subjective and

may also not be able to capture details of changes over time. Photography is an affordable method in many parts of the developing world (e.g. van Rijsoort and Jinfeng 2005 (this issue)). This method can tell if the size of important habitats is declining and why. In some cases, e.g. in the savanna woodland habitats of eastern and southern Africa, such a method might also provide some information on large mammal changes, but in general this is not the case and the method is not generally suitable for providing information on changes in abundance of animals within an area. In very poor communities, such as many parts of tropical Africa, this method might also be too expensive to be sustained over the long term.

Village group discussions

The fifth of these methods involves village group discussions. Monitoring by a small number of particularly knowledgeable forest product gatherers, hunters or fishers can provide relevant information that can be triangulated by some of the more quantitative methods such as patrol records and transect methods. The results are discussed among the group members, regularly presented at village meetings, and thereby brought to the attention of many people in order to seek their suggestions and endorsement for management decisions that will lead to conservation actions at the local level (e.g. Danielsen et al. 2000; Steinmetz 2000; Obura et al. 2002 and papers by Poulsen and Luanglath 2005; Topp-Jørgensen et al. 2005; van Rijsoort and Jinfeng 2005 (this issue)). This is an important element of locally-based monitoring as it feeds immediately back to decision-making bodies at the most effective and operational level – that of the resource users themselves.

These broad classes of methods are non-exclusive and several of our case studies use more than one (Table 2). In most cases the schemes are specific to local areas, but in Ghana, Namibia and the Philippines they have been adopted nationally (Brashares and Sam 2005; Danielsen et al. 2005; Stuart-Hill et al. 2005), and elements of the scheme in Tanzania are now also being adopted nationally (Topp-Jørgensen et al. 2005). In addition, one paper illustrates the extension of locally-based methods to a range of sites across the world (Bennun et al. 2005). As well as demonstrating the range of possible techniques, this diversity of case studies enables us to examine the merits of locally-based monitoring with respect to each of the issues raised in the Introduction.

Key issues

Cost

The costs of the monitoring schemes vary widely between our case studies due to variations in the objectives of the schemes themselves, and differences in

costs between countries (Table 1). Costs also vary with the intensity of data collection (e.g. density of field sites and frequency of data collection), accessibility of the area, density of government staff at the field level, and type of participation of the stakeholders (Table 1). These variations make the costs of the monitoring schemes difficult to compare. However, all the locally-based monitoring systems examined here have some cost, in addition to the time put into monitoring which is not then available for farming or other economic activities. The present levels of recurrent costs (excluding depreciation of equipment) range from 0.01 USD/ha/yr in Kenya and Namibia to over 10 USD/ha/yr in rivers and coral reefs of Ecuador and the Philippines (where censuses require the use of boats). The median cost of all schemes examined was 0.08 USD/ha/yr.

How do these costs compare with those of professional monitoring, and direct management? The costs of monitoring by professional scientists vary widely but as an example the programme for monitoring a protected area in Uganda cost USD 120,000 in 2001, or 3.6 USD/ha/yr (A. McNeilage *in litt*.). Other field activities required for managing conservation areas (such as law enforcement or resource management) also vary widely in cost. However, some approximate figures are informative. The costs of effectively managing protected areas in developing regions characterised by high human population density and high endemism run at very roughly 10 USD/ha/yr (Balmford et al. 2003a), dropping to 0.2 USD/ha/yr in extensive wilderness areas. However, the great majority of these costs are not currently met, either by governments or external agencies (Balmford and Whitten 2003). For example, our experience with the forest sector in Tanzania is that around 0.02–0.04 USD/ha/yr is actually available from the government Forest and Beekeeping Division for management activities in the most biologically valuable and pressurised forest areas in the country – and significantly less than this for lower priority areas. Hence locally-based monitoring can be expensive relative to the funds available for management in such countries. However, this is not necessarily the case – the median funding available for management across the range of examples presented in Table 1 is ~1.7 USD/ha/yr, or ~20 times the median cost of locally-based monitoring. Moreover, locally-based monitoring appears to be consistently cheap relative to the costs of effective management, and of professional monitoring.

Three other important points on cost emerge from our case studies. First, in seeking to calculate the costs of monitoring we have been struck by the difficulty of separating monitoring from management – in the context of these locally-based schemes the two activities are often undertaken as one (for example via patrols or village meetings). Monitoring is supposed to inform management, but in some cases it is management in its own right, as, for example, the simple presence of people showing an interest in an area generally has an unquantified but real benefit in terms of reducing threats. Hence the expenditure on the locally-based monitoring schemes summarised in Table 1

usually delivers important benefits besides monitoring *per se* (see sections below on local constituencies and decision-making).

Second, locally-based monitoring carries the potential disadvantage that the costs of monitoring can sometimes be borne disproportionately by the local communities themselves. This can be particularly problematic where the benefits they derive from such monitoring are less than the costs (e.g. Hockley et al. 2005; Topp-Jørgensen et al. 2005 (this issue)). This problem can be compounded by situations where the more powerful members of the local society capture the benefits and the poorer members are coerced into doing the monitoring work. It is important that when monitoring schemes are being established the magnitude and distribution of local costs are given careful consideration. If a conservation initiative has simply offloaded the costs of monitoring onto the local communities without associated benefits, this is probably not sustainable (see section below on sustainability).

Third, the costs of locally-based monitoring are likely to vary over time. In the majority of our case-studies the start-up cost for the monitoring system has been large and paid for by external agencies. As examples, the Philippine ranger- and community-based scheme cost around 1 million USD to establish and institutionalize in 17 protected areas (A.E. Jensen *in litt.*), and in Laos and Tanzania, comparable systems each cost over 100,000 USD to establish even though they built on the tools developed in the Philippines (E. Topp-Jørgensen and M. K. Poulsen *in litt.*). However, once it has been established and people are trained and deriving sufficient benefits to sustain the process, locally-based monitoring typically becomes considerably cheaper and new sites can be added at little cost. The Ghana ranger-based monitoring system operated for more than 30 years with monitoring incorporated within the jobs of the rangers and with salaries paid by government and only sporadic external funding (Brashares and Sam 2005 (this issue)). Once established, volunteer-based monitoring systems can also be fairly cheap (Mumby et al. 1995; Darwall and Dulvey 1996; Engel and Voshell 2002; Greenwood 2003; Roberts et al. 2005 (this issue)).

Sustainability

The definition of 'sustainable' that we use here is that it will be possible to continue the activities indefinitely at a level that ensures the objectives of the monitoring are fulfilled. In some cases (e.g. where valuable resources are rapidly disappearing), sustainability may not be crucial, and locally-based monitoring may nevertheless prove a useful tool for improving management of the area in the short term (Becker et al. 2005 (this issue)). However in general, it is clearly desirable that any scheme that is started is financially and institutionally sustainable. We have tried to assess the case studies in terms of their likely sustainability. We have also drawn out some general principles that are more likely to make the monitoring effort sustainable in the longer run.

Four of our case study examples of formalized, long-running locally-based monitoring schemes were initiated with foreign government or NGO involvement. The fact that they are now being sustained without such support provides evidence that the operational costs of locally-based monitoring in developing countries can be met when the external support ceases – as in both case studies from the Philippines, in the Laos 'village logbook', and in the Ghana example (Brashares and Sam 2005; Danielsen et al. 2005; Poulsen and Luanglath 2005; Uychiaoco et al. 2005 (this issue)). Funding to continue those schemes which have sustained themselves without support from foreign governments or NGOs has come from either the local communities or the national government. Even in these four cases, however, some small additional external inputs could almost certainly have enhanced the impact of the schemes. For example, ongoing analysis of the data collected by rangers in Ghana over the past 33 years could have prompted changes in the management regime of the reserves; instead, analysis was only retrospective and came too late for many of the reserves' large mammal populations (Brashares et al. 2001). Likewise, a little support now to strengthen training in data analysis and participatory approaches in the Philippines could improve the quality of the scaling-up process across the country.

The remaining nine ongoing monitoring schemes in this special issue are either in the early stage of implementation and their ability to sustain themselves still needs to be seen (Stuart-Hill et al. 2005; Topp-Jørgensen et al. 2005; van Rijsoort and Jinfeng 2005 (this issue)), or they currently depend on NGO input for operations and it is not known if they would persist if these inputs were terminated (Andrianandrasana et al. 2005; Becker et al. 2005; Bennun et al. 2005; Gray and Kalpers 2005; Noss et al. 2005; Townsend et al. 2005 (this issue)).

Our case studies highlight six principles that appear important in enhancing the chances of a locally-based monitoring scheme becoming sustainable without continued external support:

1. Locally-based monitoring has to address benefit flows which the community derives from the habitat or population being monitored. These are most often harvested goods, but could include indirect use benefits such as water supply (Becker et al. 2005 (this issue)), or non-use benefits such as aesthetic values (Bennun et al. 2005; Roberts et al. 2005; Topp-Jørgensen et al. 2005 (this issue)). Those benefits which are only tangible over larger scales (such as the downstream effect of water supply) are perhaps better addressed by government or NGO monitoring.
2. Second, it is not enough that the scheme addresses locally relevant benefit flows. The benefits to local people participating in monitoring should also *exceed* the costs (Topp-Jørgensen et al. 2005 (this issue)). On the one hand the benefits of the monitoring (in terms of decreased risk of stock collapse, for example) are typically only a fraction of the gross benefits derived from the population or habitat (Hockley et al. 2005 (this issue)). On the other

hand, monitoring itself can impose significant costs, in terms of time as well as resources, which may in some cases exceed its benefits (for a detailed analysis see Hockley et al. 2005). Against this, it is worth noting that there often are a number of important social benefits of monitoring – ranging from enhanced *de facto* rights to land and resources, to local status, pride in an area, and potentially enhanced training opportunities.

3. Third, monitoring schemes must pay attention to ensuring that conflicts and politics between government managers and communities do not constrain the involvement of local stakeholders in the monitoring process.
4. Monitoring should build on existing traditional institutions and other management structures as much as possible. Where the locally-based monitoring strategy has been developed in collaboration with government agencies, for example in the Iringa District of Tanzania (Topp-Jørgensen et al. 2005 (this issue)), then the measures are also likely to fit with local government systems. In many cases these measures will be simplified as local governments also have low technical capacity (few computers, poorly trained and motivated staff, etc.), enhancing the potential for synergies between locally-based monitoring and the needs of local government.
5. It is crucial to institutionalise the work at a suite of levels, from the relevant policies of the country down to the job descriptions of different government officers (Bennun et al. 2005; Poulsen and Luanglath 2005 (this issue)). In our case examples, effective institutionalisation of the monitoring has taken place in the Ghanaian protected area system of ranger-based monitoring (Brashares and Sam 2005 (this issue)). More recently, the Philippines has made locally-based monitoring a requirement for all 290+ protected areas, even though many staff have received no training in relevant methods.
6. Sustainability is enhanced where the data are stored, analysed, and remain accessible locally, even if this means there is some loss of quality. In only a few of our case examples was the data analysis performed away from the area in question – even though this is often the norm for monitoring systems established in western countries. This process of local data storage and analysis has been assisted by the decentralization process ongoing in most case study countries. It might also in turn help address one of the fundamental issues facing conservationists working in developing countries – where the capacity of government to absorb funding or new ideas is limited by the small number of qualified staff and their demanding working conditions. By involving communities and government agents at the field level the available pool of actors in the conservation arena is greatly expanded.

In conclusion, for locally-based monitoring to become sustainable the key is to keep it as simple and locally appropriate as possible. Ideally these schemes should be developed at a slow pace, paying sufficient attention to capacity-building, and using equipment which can be maintained locally with minimal recurrent costs (using toponyms instead of GPS; bicycles instead of motorbikes; ring-binders instead of electronic databases; hand-drawing skills instead

of GIS, and so on). There is often pressure, mainly from external funding agencies (Rodríguez et al. 2003) and top government officials, to use more sophisticated technologies, but if the locally-based systems are to be sustainable, these pressures are best resisted.

Likewise, there is a need to move beyond the notion that local stakeholders are too unorganised or ignorant to sustain monitoring efforts without external assistance. If sufficient incentives are in place and capacity has been well developed, there is no reason to believe that local stakeholders cannot undertake extensive responsibilities. In some areas, local people have carried out monitoring of natural resources for centuries, sustained by themselves, as an integral part of their land management. In some sub-Saharan African countries, for example, restrictions on the use of certain animals and the maintenance of sacred forest patches require some degree of local monitoring to ensure that the valued attributes are maintained. However, it is very often the case that these informal schemes are overlooked by government staff and scientists.

Ability to detect true trends

While locally-based monitoring has the potential to generate data sustainably and at low cost, many scientists remain concerned about its ability – compared with professional methods – to detect changes in populations, habitats, or patterns of resource use (e.g. Penrose and Call 1995; Brandon et al. 2003; Rodríguez 2003). Unfortunately, studies to date have been too few, and their results too inconsistent, for firm conclusions to be drawn.

We were able to find only 16 published tests comparing the performance of locally-based and professional methods: 12 from temperate regions (four terrestrial, six freshwater, and two marine), and only four (two terrestrial, two marine) from developing countries (see Table 3). Between them these tests provide cautious support for the idea that locally-based methods can identify underlying temporal or spatial variation in biological resources, but a number of important concerns emerge repeatedly. Compared with professionally-derived data, results from locally-based monitoring often have higher variance (Barrett et al. 2002; Genet and Sargent 2003), with the size or abundance of organisms sometimes being consistently under- or over-estimated (McLaren and Cadman 1999; Bray and Schramm 2001), and with mis-identification of more difficult taxa quite common (Brandon et al. 2003; Genet and Sargent 2003). Likewise, several studies caution that analysis of locally-derived data can sometimes be overly simplistic (Ericsson and Wallin 1999; Engel and Voshell 2002). However, most authors consider that these difficulties can in principle be addressed, through improved training of data collectors (Mumby et al. 1995; Darwall and Dulvy 1996; Bailenson et al. 2002; Barrett et al. 2002; Brandon et al. 2003; Janzen 2004), continued support from professional scientists (Barrett et al. 2002; Greenwood 2003), and more careful data analysis (Ericsson and Wallin 1999; Engel and Voshell 2002; Greenwood 2003; see also below).

Table 3. Summary of published comparisons of the performance of locally-based monitoring and professional monitoring.

Study and country	Biome	Who does locally-based monitoring?	Attribute(s) being monitored	Assessment of performance of locally-based vs professional monitoring
Developed countries				
Ericsson and Wallin 1999; Sweden	Terrestrial	Hunters	Moose *Alces alces* density	After appropriate calibration hunter observations predicted temporal and spatial trends in density
McLaren and Cadman 1999; Canada	Terrestrial	Volunteers	Bird species identity and abundance	Novices underestimated numbers of most bird species but improved with experience
Brandon et al. 2003; USA	Terrestrial	Volunteers	Habitat quality of forests	Volunteer identification of difficult trees and counts of abundant shrubs poor but could be addressed through better training
Greenwood 2003; UK	Terrestrial	Volunteers	Abundance of breeding birds	Ongoing input from professional scientists into survey design and data analysis guarantees quality and ensures high-level use of results
Bray and Schramm 2001; USA	Freshwater	Anglers	Catch per unit effort and size of sport fish	Angler data on catch per unit effort and length generally not correlated with professional, and give very limited coverage of certain species
Hoyer et al. 2001; USA	Freshwater	Volunteers	Species richness and abundance of aquatic birds	Volunteer data on species richness and abundance accurately matched those collected by professional biologists
Fore et al. 2001; USA	Freshwater	Volunteers	Species richness and dominance of benthic communities	After training results of volunteer surveys matched those of professional biologists
Engel and Voshell 2002; USA	Freshwater	Volunteers	Ecological condition, from benthic community structure	Initial volunteer protocol consistently overrated ecological condition, but volunteer measures using modified sampling and analysis protocols closely matched professional measures
Genet and Sargent 2003; USA	Freshwater	Volunteers	Anuran species identity and abundance, from calls	Volunteer estimates of abundance showed high variability, with some species misidentified
Boudreau and Yan 2004; Canada	Freshwater	Volunteers	Spread of invading water flea	No difference in detection by volunteers and professional biologists
Schmitt and Sullivan 1996; USA	Marine	Volunteers	Fish species identity and abundance	Results consistent with those of previous professional studies
Barrett et al. 2002; Australia	Marine	Volunteers	Identity, size and abundance of harvested species	Volunteer data on species identities and sizes were more variable and less reliable than those of professional biologists, but training and data amalgamation could improve usefulness
Developing countries				
Hellier et al. 1999; Mexico	Terrestrial	Local communities	Forest cover and abundance of harvested species	Some contradiction with professionally-derived data on vegetation change
Noss 1999; Central African Republic	Terrestrial	Hunters	Abundance and density of game species	For 2 out of 4 species hunter-based method could generate only abundance indices, not density estimates
Mumby et al. 1995; Belize	Marine	Volunteers	Abundance of reef organisms; substrate composition	Accuracy and consistency of volunteer data varied with habitat type and taxon and were lower in deeper water, but did not increase with experience
Darwall and Dulvy 1996; Tanzania	Marine	Volunteers	Fish species identity and abundance	Precision increased sharply with experience

The general shortage of tests is reflected in the present issue. Only two of our case studies compare findings between locally-based and professional monitoring; no others included parallel use of both types of methods. Uychiaoco et al. (2005) report that out of four community-collected measures of reef benthic cover and fish abundance, only one was correlated with the equivalent data collected by biologists, with local people's measures of fish abundance being far more variable than those of professional scientists. In contrast, Roberts et al. (2005 (this issue)) find that annual variation in the proportion of days on which different bird species are caught during mist-netting at a reserve (which they suggest might be indicative of proportional recording on amateur birdwatchers' day lists) could predict local and even national temporal trends in species' abundance.

Two other case studies use power analysis to examine how far spatially and temporally intensive sampling regimes could be pared-down yet still detect key trends with a statistically acceptable degree of confidence. Both reveal that the lower limits to worthwhile sampling effort are surprisingly high. Thus using data from harvested crayfish populations in Madagascar, Hockley et al. (2005 (this issue)) report that a single village would have to invest at least 300 person-days per year in monitoring to have an 80% probability of detecting a population decreasing by 20% over 5 years. This may be a worst case scenario however. Using Ghanaian ranger-based wildlife data, Brashares and Sam (2005, this issue) show that survey efforts could be decreased by 25–50% before their ability to detect trends in the abundance of large mammals and hunters was substantially reduced. The Ghana study also provides some evidence that a high spatial intensity of sampling may be more important than high temporal intensity.

Taken together, the literature, the case studies, and our symposium discussion support four general conclusions about the relative ability of locally-based monitoring to detect changes in biological resources:

1. Further quantitative comparisons of the findings of locally-based and professional monitoring are badly needed, especially in developing countries, and in circumstances where data-gatherers have received little or no formal scientific education (cf. Table 3). We are not suggesting that every locally-based scheme needs to be calibrated against a professional method – this would be logistically impractical, unaffordable, and would imply widespread distrust of local communities. However we do suggest that all methods (Table 2) need careful and well-documented checking against broadly accepted techniques, across a range of local contexts (see also Engel and Voshell 2002). Unless this costly and time-demanding task is done, there will always be the concern that, however well intentioned, management interventions derived from local monitoring might in some cases be directed towards inappropriate targets.
2. Locally-based methods are in general more vulnerable than professional techniques to various sources of bias, which decrease their accuracy (defined as the closeness of the resulting measures to their true values; Table 4a). Key

Table 4. Key potential constraints to the accuracy and precision of locally-based and professional monitoring of biological diversity and resource use.

	Locally-based monitoring	Professional monitoring
(a) Constraints to accuracy		
Lack of measurement experience	2	1
Conflict of interest	3	1
Inconsistent use of methods, across time or observers	3	1
"Fossilized" perceptions	1–2	0
Unrepresentative spatial or temporal spread of sampling effort	1–3	1
Poor identification, field or language skills	1–3	1–3
(b) Constraints to precision		
Small sample size	3	2
Poor temporal or spatial spread of sampling effort	1–3	1
Physical loss of data	2	1
Inconsistent use of methods, across time or observers	3	1

0 = not a problem; 1 = limited problem; 2 = potentially important problem; 3 = serious constraint.

potential problems include a lack of measurement experience on the part of observers (which often leads to over-estimates of abundance and size – e.g. Uychiaoco et al. 2005 (this issue)); potential conflicts of interest (with recorders perhaps inadvertently providing data which are biased towards managers' preconceptions); a tendency, in the absence of careful documentation, for methods to drift over time, or for results to reflect long-term ('fossilized') perceptions more than current trends (e.g. Andrianandrasana et al. 2005 (this issue)); and the potential for the spatial or temporal coverage of monitoring to be unrepresentative of the entire system of interest.

3. Besides accuracy, the utility of monitoring is limited by the precision of the results (that is, the closeness of repeated measures of the same quantity to each other; Table 4b). Sources of low precision (leading to high variance around the estimated true value of the attribute of interest) include small sample sizes; overly thin or patchy temporal or spatial deployment of sampling effort; the physical loss of data; and the inconsistent application of methods, either through time or across observers. These problems can affect all sample-based monitoring, but are likely to be a particular problem where financial or professional human resources are tightly limited.
4. Accuracy, precision, and overall usefulness are all best addressed by careful planning. A guide for developing systematic monitoring, adapted for the community-, ranger- or volunteer-based context, is provided in Box 1 (adapted from Royal Society 2003; Green et al. 2005). Important steps that in our experience are all too often ignored include (i) broad consultation right at the outset, with all key stakeholders to jointly determine the aims of the monitoring programme, coupled with ongoing checking that the monitoring addresses their concerns; (ii) explicit consideration during the design

stages of likely biases, and of how best to deploy sampling effort to enhance precision; (iii) thorough training of data gatherers; and (iv) establishment of mechanisms for feeding results directly into management.

Provided that these principles of effective monitoring are addressed then in our view there is no reason that locally-based methods should yield results that are in any way inferior or less reliable than those derived by professional monitoring (see also Yoccoz et al. 2003). Rather than being seen as "quick and dirty", if properly designed such approaches have the potential instead to be low cost, rapid, and locally relevant. In reality, in many areas the alternative to local schemes would be no monitoring at all.

Decision-making and action

The purpose of management-oriented monitoring is to influence decision-making and action on the ground. Without this, there is little reason for carrying out the monitoring. We have tried to assess the case studies provided in this issue in terms of their ability to influence decision-making. We have also tried to give a general characterization of the decisions and actions that arise from locally-based monitoring.

The case studies provide evidence that in the schemes examined a large number of conservation and natural resource management decisions are taken on the basis of local monitoring. Quantitative data from cases in Tanzania and the Philippines suggests that these decisions are highly relevant from a biodiversity conservation perspective because a large proportion of the decisions taken addressed the most serious threats to the biodiversity of the sites and led to change in local policies with potentially long-term impacts (Danielsen et al. 2005 and in prep.; Topp-Jørgensen et al. 2005 (this issue)). For instance, patrol records and village group discussions prompted a village head to issue a village ordinance banning electro fishing to protect the freshwater fish resources (NORDECO and DENR 2001). Likewise, based on data from transects and village group discussions, an indigenous Obo Bagobo chieftain issued a byelaw on a closed season for hunting Philippine warty pig *Sus philippensis*. Similarly, the management council of a protected area decided to develop a pasture management plan for communal lands with local goat keepers after observing signs of serious erosion on photos from fixed point photography.

There also seems to be evidence that community-based methods are more effective than methods without community participation in generating decisions (Danielsen et al. in prep.). In the case studies where monitoring did not lead to decision-making, this was because the feedback loop from data and analysis to decision-making had yet to be developed or institutionalised (Bennun et al. 2005; Brashares and Sam 2005; Roberts et al. 2005 (this issue)), or because the community members participating in the monitoring had not yet gained authority over the land and resources (Noss et al. 2005 (this issue)).

In general, the experience of the case studies suggests that locally-based monitoring and professional monitoring lead to substantially different kinds of decisions (Table 5). Decisions from locally-based monitoring are often taken promptly and at the local level (see also Kerr et al. 1994), in response to immediate threats to the environment. These decisions usually result in actions based on community rules and enforcement, such as local bylaws governing resource use (e.g. van Rijsoort and Jinfeng 2005 (this issue)). Such actions are aimed not only at protecting habitats and/or species but also at ensuring a continued supply of benefits for the local human communities. The decisions are often respected by the locals and the associated actions are relatively sustainable, both financially and organisationally, probably because they are nested within existing local institutions (Becker et al. 2005 (this issue)). This kind of monitoring generally provides fast and meaningful feedback to inform adaptive management.

In comparison monitoring by scientists may be slow in leading to decisions, but the scale of decision may be very different (Table 5). Professional monitoring has the potential to influence national and global policies and funding flows. Scientists often have better access than local communities to high-level decision-makers. For instance, results from locally-based monitoring are unlikely to persuade the US government to ratify the Kyoto Protocol, whereas findings from professional monitoring potentially could. Decisions from locally-based monitoring will generally not have impacts beyond the local scale unless the locally-based monitoring is embedded within or linked to a national or international scheme that feeds the data up to the levels at which governments, international agencies and multi-national corporations operate (see section below on tracking of larger-scale trends, and papers by Bennun et al. 2005 and Roberts et al. 2005 (this issue)). Several of our case studies did do this and it is noteworthy that in some, politicians and governments did pay attention (e.g., Andrianandrasana et al. 2005; Gray and Kalpers 2005 (this issue)). Unfortunately, in the only example we know in which national level aggregation of locally-based monitoring data has been institutionalised (the Philippines), the national work suffers from chronic underfunding and weak institutional support.

Why does locally-based monitoring lead to locally-based decision-making? Experience from the case studies suggests three reasons. Firstly, unlike monitoring by scientists, participatory monitoring encourages decision-making by providing an institution (e.g. village discussion groups composed of particularly knowledgeable villagers) or a forum (e.g. meetings between rangers and local residents) for regular discussion of local natural resource management. Monitoring provides a reason to discuss better ways of managing resources. Secondly, participatory monitoring provides local residents with otherwise rare opportunities for collaboration with government staff and for representation in local decision-making on natural resources. Understanding the local ways of thinking, and of making decisions, is therefore important for the success of local schemes. Thirdly, decision-making based on local monitoring is not swamped by government bureaucracy because many of the decisions are taken

Table 5. Comparison of locally-based and professional monitoring in terms of decision-making and action.

	Locally-based monitoring	Professional monitoring
Time from data sampling to decision-making?	Short	Long
Who uses the monitoring for decision-making?	Local villagers and government authorities at the field level (e.g. local authorities or protected area staff)[a]	Protected area management authorities, national governments, scientific advisors to governments and international NGOs
What are the decisions arising from monitoring usually taken in response to?	Immediate threats to the environment; perceived and/or obvious problems that residents and government field staff can see and grasp	Data-based trends in species abundance, species populations and habitat extent/condition
What threats are addressed by the decisions arising from monitoring?	Immediate threats to the environment (e.g. forest degradation, overharvesting)	Immediate as well as root cause[b] threats to the environment
What actions do the decisions arising from monitoring result in?	Actions based on community rules and enforcement, aimed at protecting habitats or species or ensuring continued supply of benefits for the local human communities can inform higher-level decisions if data appropriately synthesized across studies	National park interventions, permit systems, policy changes in other sectors such as agriculture or transport
Are the actions likely to be sustainable?	Can be sustainable, especially if the actions are nested within existing local institutions[c]	Can be sustainable, if, e.g., governments sign and implement conventions[d]
Are the decisions arising from monitoring respected by local residents?	Decisions are often respected when existing village institutions are involved	The respect paid varies from place to place
Are the decisions arising from monitoring respected by government or private sector?	The respect paid depends on the context	The respect paid depends on the context
Contribution of decisions arising from monitoring to adaptive management?	Fast and meaningful feedback to the management level	Slow and commonly limited feedback to the management level

[a] Potentially also national government, if the monitoring is embedded within or linked to a system that rolls the data back to levels where national policy-makers can access and use it.
[b]E.g. climate change, energy policy, subsidies, international trade agreements.
[c]See Danielsen et al. 2005 (this issue).
[d]Assuming funds and political will are available to support their implementation.

promptly by the same people or institutions that collect the data (Danielsen et al. 2005 (this issue)).

Moving from decision-making to action, does locally-based monitoring in developing countries lead to improved management of natural resources? Obtaining evidence for this is constrained by the difficulty of measuring improved management by a standard scale across different habitats. Moreover, the true impact may only be discernible in the long term and most of the locally-based schemes underway are still young. In one of our cases, however, the main threat to biodiversity – wildlife hunting – was documented as being partly or fully reduced in a reserve as a result of actions resulting from locally-based monitoring (Topp-Jørgensen et al. 2005 (this issue)). In two other cases, locally-based monitoring led to successful lobbying for the gazetting of a new protected area (Becker et al. 2005; Townsend et al. 2005 (this issue)). There is, in general, substantial evidence from several of our cases to suggest that community-based monitoring rapidly leads to many relevant conservation management interventions. There is as yet, however, limited documentation of the long-term outcome of these interventions.

Local constituencies

We have tried to assess the benefits provided by the ranger- and community-based monitoring schemes in terms of building local constituencies and enhancing local capacity. The ranger-based monitoring schemes all contributed to empowering the rangers (Table 6). Ranger participation in monitoring increased their resource management capacity, field experience and naturalist skills, and their motivation and pride in their work (e.g. Gray and Kalpers 2005 (this issue)).

Our case studies on community-based monitoring schemes documented four major types of benefit in terms of building local constituencies:

1. The community-based schemes led to improved collaboration and communication between local stakeholders and government authorities. Quantitative data from the Philippines suggests that every third conservation management intervention generated by locally-based monitoring was collaborative between government and the members of the community. Related to this, some of the schemes also led to increased trust between the local stakeholders, and to more transparent, accountable and democratic decision-making, thereby fostering a sense of good governance (e.g. Andrianandrasana et al. 2005; van Rijsoort and Jinfeng 2005; Topp-Jørgensen et al. 2005 (this issue)).
2. The community-based schemes led to enhanced awareness and education, and change in attitude towards more environmentally sustainable natural resource management among the local participants (see also Kerr et al. 1994; Ticheler et al. 1998; Obura et al. 2002). For instance, in Tanzania, local involvement in monitoring provided the people with a direct and

Table 6. Key benefits of ongoing locally-based biodiversity monitoring schemes in terms of building local constituencies.

Case study[a]	Country	Who compiles data[b]	Empowerment of protected area staff	Improved collaboration and communication between local stakeholders and authorities	Enhanced awareness and change in attitude among locals	Increased compliance with laws	Strengthening of community-based resource management systems
van Rijsoort and Jinfeng 2005	China	R/C	+	+	+	+	+
Bennun et al. 2005	Kenya	C			+		
Poulsen and Luanglath 2005	Laos	R/C	+	+	+	+	+
Stuart-Hill et al. 2005	Namibia	C		+	+	+	+
Danielsen et al. 2005	Philippines	R/C	+	+	+	+	+
Topp-Jørgensen et al. 2005	Tanzania	C		+	+	+	+
Noss et al. 2005	Bolivia	C		+	+	+	+
Becker et al. 2005	Ecuador	C/V		+	+	+[c]	+
Brashares and Sam 2005	Ghana	R	+				
Gray and Kalpers 2005	Uganda, Rwanda, DRC	R	+				
Townsend et al. 2005	Ecuador	C		+	+	+	+
Andrianandrasana et al. 2005	Madagascar	C		+	+	+	+
Uychiaoco et al. 2005	Philippines	C		+	+	+	+

+ = benefit documented in this study.

[a] Source of information (this issue, and correspondence with the authors).

[b] C = community members; R = government rangers; V = volunteers (from abroad).

[c] Only compliance with local rules.

tangible link between personal income and resource conservation (Topp-Jørgensen et al. 2005 (this issue)). In Ecuador, participation in monitoring changed the attitude of many Cofán Indians in relation to turtle harvesting, from one of exploitation to one of managed harvesting and record-keeping (Townsend et al. 2005 (this issue)).

3. The community-based monitoring led to increased compliance with laws. The monitoring motivated the local stakeholders to agree on and then uphold resource-use regulations (see also Blyth et al. 2002). Among indigenous people in Bolivia, locally-derived monitoring data were considered to hold great weight in community discussions because 'outside experts were not blamed for inventing data' (Noss et al. 2005 (this issue)). Since local residents tend to comply with locally-agreed decisions, community-based monitoring may be more effective than professional monitoring in arresting over-exploitation and degradation of natural resources.
4. The community-based schemes translated local knowledge into biological or bureaucratic language, thereby strengthening existing community-based resource management systems and empowering local residents (see also Marks 1994; Ticheler et al. 1998). For instance, indigenous knowledge was absorbed into locally-based monitoring and used in a court case on oil contamination in Ecuador (Townsend et al. 2005 (this issue)). Likewise, experience from the Philippines suggests that, as a result of locally-based monitoring, indigenous resource-use regulation schemes were being re-inforced through local government recognition. In addition, indigenous people became increasingly recognized as resource co-managers.

Experience from our cases and from the few published studies of other community-based schemes in developing countries, we were able to find (Marks 1994; Ticheler et al. 1998; Steinmetz 2000; Obura et al. 2002) suggests that the four above-mentioned benefits are almost universal outcomes of community-based monitoring schemes on sites where the methods can be implemented (see Table 6).

One further benefit was reported in the community-based monitoring case studies in Madagascar and the Philippines, where the monitoring led to a more socially acceptable and effective approach to enforcement (Andrianandrasana et al. 2005; Danielsen et al. 2005 (this issue); and J. Durbin *in litt.)*. While scientists and government staff may be seen as representatives of an oppressive and interfering state, monitoring schemes where local people have direct access to decision-making are less likely to create antagonism. This may explain some of the success of the local schemes in building local constituencies.

Which particular monitoring method was most effective in strengthening the local constituencies? Data are limited but cross-method comparison in the Philippines provides evidence that the village group discussion method (Table 2) was strikingly more effective than the others in improving collaboration between stakeholders, motivating locals to participate in resource-use regulation, and empowering local stakeholders.

Tracking larger-scale trends

As well as providing data to inform local management decisions, locally-based monitoring has the potential to shed valuable light on changes in biodiversity and ecosystem services at national and even global scales. Papers in this special issue outline two systems currently in development – BirdLife's Important Bird Areas monitoring scheme, and Project Kagu – which have been explicitly designed to allow such upwards movement of data, and ultimately to permit global analyses (Bennun et al. 2005; Roberts et al. 2005 (this issue)). To the extent that systems like this can be implemented and replicated, important global monitoring gaps can be plugged, at relatively low cost, while at the same time increasing local people's input to higher-level decision-making.

Certain kinds of global and national data gaps seem particularly well-suited to input from local schemes (Table 7). In terms of trends in species and populations, the use of data from volunteer bird counts to address European Union farming policy demonstrates eloquently that appropriate analysis of locally-derived data can be of immense international value (Greenwood 2003; Gregory et al. 2005). Less ambitious schemes can also be useful, providing input into large-scale meta-analyses such as WWF's Living Planet Index of vertebrate population trends (Loh et al. 2005; see Figure 1); this is especially important given the paucity of tropical studies available for such analyses. Turning to habitats, while the extent of some biomes is most efficiently monitored top-down, via remote-sensing, for many others habitat loss proceeds primarily via degradation (and loss of content) rather than wholesale conversion. This is for instance the case in temperate and tropical grasslands, fragmented forest landscapes, freshwater (ponds, lakes, streams, rivers) and marine habitats such as inter-tidal areas, coral reefs and estuaries. Few large-scale programmes exist for tracking such changes in habitat condition, but new meta-analytical techniques mean that data from diverse small-scale studies can be usefully synthesized to elucidate regional and potentially even global patterns (Côté et al. 2005). Data from locally-based monitoring could also be aggregated to generate larger-scale overviews on threats (such as unregulated artisanal harvesting) operating at relatively small scales, and on the local impacts of management interventions.

But perhaps the greatest scope for locally-derived inputs to large-scale measures of change is in tracking the delivery of goods and services from natural ecosystems. These form a prime focus of the Convention on Biological Diversity's 2010 target (UNEP 2002), yet are extremely hard to monitor using a top-down approach. We suggest that appropriate meta-analyses of locally-generated data on flows in benefits such as harvests of wild species, and reliable provision of clean water, offer the best opportunity for measuring global-level progress against the 2010 target for ecosystem services. Yet several steps must be taken in order for this considerable potential of locally-based data to be realised.

Table 7. Comparison of suitability of locally-based and professional monitoring in relation to what needs to be monitored, how the area is managed, what threatens it, and the availability of resources for monitoring.

		Locally-based monitoring	Professional monitoring
What needs to be monitored	Trends in species or populations	Yes, but some species not possible (cryptic)	Yes, but in practice often difficult
	Trends in extent or condition of habitats	Yes, especially condition	Yes, especially extent at large-scale, but remote-sensing not possible for some biomes
	Trends in ecosystem services	Yes, for those delivered at local scale	Very difficult for local-scale benefits; modelling and remote sensing can be applied to larger-scale benefits (e.g. carbon sequestration)
	Trends in threats	Yes, for those that operate locally (e.g. local overharvesting, habitat degradation)	Yes, mainly for those operating at large scales (e.g. habitat clearance, climate change)
	Trends in the impacts of management interventions	Yes, for those that operate locally	Yes, mainly for those that operate at large-scale
How the area is managed	Extent of local benefit-sharing	Local flow of benefits (e.g. resource harvesting) permitted	Any area
	Level at which management change is needed	Village or protected area	Government or protected area
What the threats are	Scale over which threats operate	Mainly local, some national	Mainly national or global
Availability of resources for monitoring	Financial resources for set-up and training	High	High
	Recurrent financial resources	Low	High

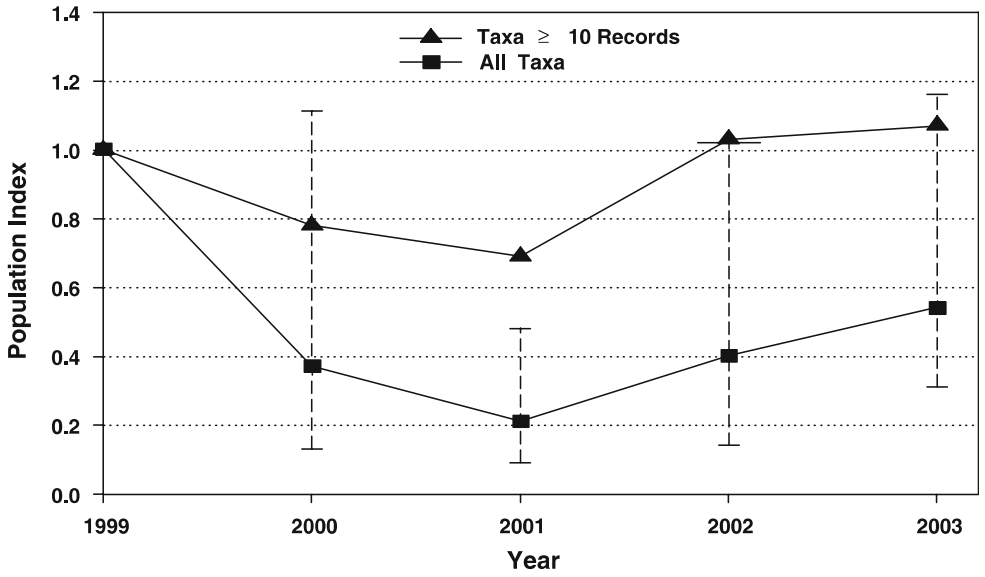

Figure 1. Example of the potential of locally-based monitoring of biodiversity in developing countries to provide input into larger-scale meta-analyses. The graphs show trends in population samples in forest ecosystems of Mindanao, the Philippines, using data from ranger-based transects. The figure is based on average trends in populations of 28 bird and 7 mammal taxa (■; including 95% confidence intervals obtained by a bootstrap method with 1000 replications) and only those taxa with 10 or more records (▲; 16 bird and 4 mammal species). To prepare the graphs, we used the analytical method of WWF's Living Planet Index described by Loh et al. (2005) on a set of data from Mt. Kitanglad Range (scheme described in Danielsen et al. 2000 and 2005 (this issue)). The Living Planet Index represents the average change within an entire collection of population samples over a given study period, giving equal weight to each species, whether common or rare, and to small and large populations (Kapos et al. 2004). The resulting trend line shows changes in species abundance and, by implication, the condition of the ecosystems in which they occur. Three potential biases of using these locally-derived transect data for generating species population trend indices emerge and need to be recognized (see also Kapos et al. 2004). Firstly, the sample size of most taxa was small, with 43% of the taxa being recorded in numbers less than 10. If the low-density forms were omitted from the analysis, the results would differ (see ▲). This bias is inherent to tropical forests where the numbers of low-density taxa are large. Secondly, the transects generated data on birds (80% of the 35 taxa) and mammals (20%), generally taxa at the upper trophic levels. No invertebrates were recorded. Cross-taxon species abundance patterns in tropical forests do not necessarily coincide. This bias is difficult to adjust for but needs to be taken into consideration when using the index. Thirdly, there is a geographic and habitat bias, because the index was only based on data from one site. Sensitivity analyses suggest that data from a minimum of around 45 populations instead of 35 would be needed (Kapos et al. 2004). This can be adjusted for by including data from a larger number of widely distributed sites. Fortunately, for heterogenous landscapes, many small samples provide a better sampling of the meta-community than few large samples (Wiens 1989; see also Brashares and Sam 2005 (this issue)).

Most importantly, for locally-based information to be useful at larger scales, monitoring schemes will need to be established in more sites and countries, and the resulting data must be as unbiased and precise as possible (see section on ability to detect true trends). Results can also only be synthesized where many programmes have monitored the same attributes (such as the rate of offtake of medicinal plants, or changes in condition of rangelands). They need not all use a single standardized technique – this would be difficult given the importance of

Box 1. Six steps for developing locally-based monitoring of biodiversity and resource use (modified from Royal Society 2003; Green et al. 2005).

1. Discuss within the responsible institutions and with interested stakeholders the need for, and the aims of, management-oriented monitoring. In particular, discuss:
   - Which aspects of biodiversity and resource use are you interested in?
   - What questions do you want the monitoring to answer?
   - What are you likely to do with the results?
   - When are the results of monitoring needed?
   - What level of precision and accuracy is required?
   - What incentives are required to ensure community, ranger or volunteer engagement?
2. Use existing knowledge, including that of villagers and local staff, to develop a model of the system, even if it is only conceptual. For example, the topic of interest may be the number of turtles than can be harvested sustainably from an area. This cannot be measured directly, but developing a simple model of how this relates to measurements that are feasible and realistic for community members, rangers or volunteers to conduct (such as the number of nesting females on a communal beach) makes the limitations of the assessment explicit.
3. Agree on an institutional framework for using the results of monitoring for adaptive management.
   - Agree on who takes decisions, and how monitoring results reach this body
   - Develop and agree on mandates and responsibilities of the involved parties
   - Wherever appropriate, the monitoring should be embedded within existing institutions
4. Develop a sampling strategy that specifies who measures what, how, where and when.
   - Discuss the usefulness, costs and difficulty of alternative measures, including any existing schemes underway
   - Identify which species, areas, or resource uses are to be monitored
   - Design a sampling strategy which pays explicit attention to potential sources of bias and in which the spatial and temporal deployment of sampling effort is appropriately stratified to maximise precision given available resources
   - Train data gatherers to follow a common protocol which is written down; if guidelines and training materials from other monitoring schemes are relevant, ask to use them, and adapt the materials to the local context
   - Agree on how and where to store data
   - Conduct a pilot study to test feasibility of data collection protocols; check with stakeholders whether the resulting data address their needs
5. Begin implementation on-the-ground. Important steps include:
   - Store data in its most disaggregated form and with details of exactly how it was collected
   - Record sampling effort, who collected the data, and precise locations of field study areas
   - Keep raw data for checking and re-interpretation
   - Ensure that checks are carried out to keep errors in recording and data storage at an acceptable level
   - Analyse the data, and feed results back to data gatherers
   - Wherever possible compare results with those of other locally-based or professional approaches
   - Provide results to decision-making body, and check they are fit-for-purpose
   - Ensure that data gatherers are aware of management decisions arising from their data
6. Discuss the results with the local/national stakeholders and revise the strategy for the monitoring accordingly.
   - Address sustainability issues such as post-project funding and recurrent training needs
   - Keep track of management interventions resulting from the monitoring
   - Make data available on open access database, if possible
   - Facilitate the development of national policy, guidelines or tools for monitoring.

the monitoring schemes being autonomous, and would preclude schemes from being responsive to local circumstances and needs. However, it is important that only a relatively small number of methods, each well replicated, is used across the set of studies to be analysed. Provided this is the case then meta-analytical techniques can be used to check (and if necessary adjust) for differences in results being due to differences in field methods (for a worked example see Côté et al. 2005).

Recommendations

Suitability of locally-based and professional approaches

The relative utility of locally-based and professional approaches is explored in Table 7. We argue that locally-based monitoring can generate cheap and locally meaningful data on the condition of habitats and the population sizes of larger and more obvious species. It can also provide evidence of changes in local ecosystem benefits such as reliable provision of clean water, as well as on local threats such as habitat degradation. Local methods are however unlikely to provide quantitative data on large-scale changes in habitat area, or on populations of cryptic species that are hard to identify or census reliably. Likewise, they are not suitable for examining large-scale ecosystem benefits such as carbon-sequestration or global-scale threats such as climate change.

Investments in monitoring should be carefully tailored according to the aims of the studies. Where changes, threats or interventions operate over large scales, or in complex fashions, locally-based methods are less likely to yield useful data and management solutions than professional approaches. But where the issues are relative small-scale and patterns of causality are likely to be relatively straightforward, locally-based methods can prove cheaper, more sustainable, and more effective than professional approaches.

Fertile ground for the development of locally based monitoring appears to be where local people are interested in monitoring attributes of interest that are under their direct control (benefits), or which they are concerned about such as threats (see Stuart-Hill et al. 2005 (this issue)). Monitoring attributes that are only of concern to outsiders are hard to sustain in a locally based scheme, and may therefore need to be undertaken by professional scientists.

Design

We recommend that scientists and managers who would like to establish systematic community-, ranger- or volunteer-based monitoring of biodiversity and resource use employ the steps outlined in Box 1. The monitoring

should be kept as simple and locally appropriate as possible. Attention should be paid to capacity-building of data gatherers in field techniques, species identification skills, and how to make use of the data. The monitoring should be institutionalised within existing management structures at both local and national level and preferably be embedded within a scheme that feeds the data up to national or international levels. Unnecessary changes in the monitoring should be avoided and, if it has to change, efforts should be made to nest previous scheme within new scheme. Management interventions resulting from the monitoring should be tracked as a possible indication of the scheme's management impact and to provide direction.

Tasks ahead

The experiences from the case studies suggest that, if properly designed, locally-based monitoring can address several of the shortfalls of professional monitoring. Most importantly, local approaches have the potential to be low cost, rapid, locally relevant, and capable of building capacity among the local constituents. However, without rigorous validation studies, professional scientists will remain sceptical about the results of local monitoring schemes. We therefore recommend quantitative assessments of the ability of all locally-based methods (Table 2) to detect changes in populations, habitats, or the provision of goods and services.

We also recommend that scientists and managers explore the potential of amalgamating locally-based monitoring schemes to provide input into tracking larger-scale trends in the status of populations and habitats, the services they provide, and the threats they face. Our symposium suggested that one potentially powerful device for achieving these steps (and for supporting locally-based monitoring schemes more generally) could be the establishment of a dedicated website. This could host a catalogue of existing locally-based monitoring schemes, and act as a place where fieldworkers could access one another's experience and gain advice on how to collect, store and analyse data.

Establishment and maintenance of such a web-site should be complemented by regional workshops to exchange experiences, mutually agree on standards, and identify good practice. Disparate datasets could then be compatible enough for meta-analyses, in which case this initiative could act as a focal point for amalgamating results for analysis and subsequent input into national-, regional- and global-level measures such as those being developed for the 2010 target (UNEP 2004; Balmford et al. 2005; Convention on Biological Diversity 2005). We envisage that this initiative could simultaneously facilitate the development of a virtual community of local monitors, improve practice on the ground, and raise the profile of locally-based monitoring at national and international levels.

Acknowledgements

The costs associated with this symposium were covered by a grant from NORDECO (Copenhagen, Denmark). We are very grateful to J. Fjeldså and our colleagues for inspiring discussions, to J. Fjeldså, M. Funder and C. Harboe for diligently assisting with the editorial work, to E. Topp-Jørgensen for searching for literature, to B. Christensen for assisting with Figure 1, and to A. Foldschack and D. K. Hendrichsen for taking care of logistics during the symposium. We are indebted to all authors for their contributions and for sharing unpublished information with us. The following gave advice or reviewed manuscripts: S. W. Andersen, T. Blomley, K. Brandon, J. Brashares, B. Child, S. Christiansen, T. Dodman, P. Donald, W. Duckworth, M. Enghoff, J. Fjeldså, H. Fox, P. Franks, M. Funder, J. Harstad, G. Hilton, H. Hübertz, A. E. Jensen, J. Jones, Å. Jørgensen, S. Ling, K. MacKinnon, A. McNeilage, S. Milledge, J. van Rijsoort, S. O'Connor, I. Oetting, M. V. Pedersen, K. Pfleigner, A. Plumptre, M. K. Poulsen, J. F. Rasmussen, G. Shea, D. Sheil, S. Shen, T. Skielboe, S. Stolton, G. Stuart-Hill, E. Topp-Jørgensen, W. Townsend, S. Wells, T. Whitten, U. Wilken, and D. Wilkie. We are also grateful to those who made presentations at the symposium without submitting a paper for publication (S. Christiansen, S. Eguino, J. Fjeldså, T. Whitten and D. Yonten). We thank G. Stuart-Hill for accepting at short notice to write a paper for this issue. Data for Figure 1 were made available by F. Mirasol of Mt. Kitanglad Range Natural Park, Bukidnon, the Philippines. Presentations at a follow-up seminar of Danida were kindly made by J. Brashares, H. Nøhr, I. Oetting, E. Topp-Jørgensen and D. Yonten. We also wish to thank A. Bull for the invitation to produce this thematic issue.

References

Andrianandrasana H.T., Randriamahefasoa J., Durbin J., Lewis R.E. and Ratsimbazafy J.H. 2005. Participatory ecological monitoring of the Alaotra wetland in Madagascar. Biodivers. Conserv. 14: 2757–2774.

Bailenson J.N., Shum M.S., Atran S., Medin D.L. and Coley J.D. 2002. A bird's eye view: biological categorization and reasoning within and across cultures. Cognition 84: 1–53.

Balmford A., Crane P., Dobson A.P., Green R.E. and Mace G.M. 2005. The 2010 challenge: data availability, information needs and extraterrestrial insights. Phil. Trans. R. Soc. London. B 360: 221–228.

Balmford A., Gaston K.J., Blyth S., James A. and Kapos V. 2003a. Global variation in conservation costs, conservation benefits, and unmet conservation needs. Proceedings of the National Academy of Sciences USA 100: 1046–1050.

Balmford A., Green R.E. and Jenkins M. 2003b. Measuring the changing state of nature. Trends. Ecol. Evol. 18: 326–330.

Balmford A. and Whitten T. 2003. Who should pay for tropical conservation, and how could the costs be met? Oryx 37: 238–250.

Barrett N., Edgar G. and Morton A. 2002. Monitoring of Tasmanian inshore reef ecosystems. An assessment of the potential for volunteer monitoring programs and a summary of changes within

the Maria Island Marine Reserve from 1992–2001. Tasmanian Aquaculture and Fisheries Institute Technical Report Series 53 pp.

Becker C.D., Agreda A., Astudillo E., Constantino M. and Torres P. 2005. Community-based surveys of fog capture and biodiversity monitoring at Loma Alta, Ecuador enhance social capital and institutional cooperation. Biodivers. Conserv. 14: 2695–2707.

Bennun L., Matiku P., Mulwa R., Mwangi S. and Buckley P. 2005. Monitoring Important Bird Areas in Africa: towards a sustainable and scaleable system. Biodivers. Conserv. 14: 2575–2590.

Bibby C., Burgess N.D., Hill D. and Mustoe S. 2000. Bird Census Techniques, 2nd ed. Academic Press, London, UK350 pp.

Blyth R.E., Kaiser M.J., Edwards-Jones G. and Hart P.J.B. 2002. Voluntary management in an inshore fishery has conservation benefits. Environ. Conserv. 29: 493–508.

Boudreau S.A. and Yan N.D. 2004. Auditing the accuracy of a volunteer-based surveillance program for an aquatic invader *Bythotrephes*. Environ. Monit. Assess. 91: 17–26.

Brandon A., Spyreas G., Molano-Flores B., Carroll C. and Ellis J. 2003. Can volunteers provide reliable data for forest vegetation surveys?. Nat. Area. J. 23: 254–262.

Brandon K. and Wells M. 1992. Planning for people and parks: design dilemmas. World Dev. 20: 557–570.

Brashares J.S., Arcese P. and Sam M.K. 2001. Human demography and reserve size predict wildlife extinction in West Africa. Proceedings of the Royal Society of London, Series B 268: 2473–2478.

Brashares J.S. and Sam M.K. 2005. How much is enough? Estimating the minimum sampling required for effective monitoring of African reserves. Biodivers. Conserv. 14: 2709–2722.

Bray G.S. and Schramm H.L.Jr. 2001. Evaluation of a statewide volunteer angler diary program for use as a fishery assessment tool. N. Am. J. Fish. Manage. 21: 606–615.

Caldecott J. 1998. Designing Conservation Projects. Cambridge University Press, Cambridge, UK 334 pp.

Convention on Biological Diversity 2005. The 2010 Biodiversity Target – Indicators. www.biodiv.org/2010-target/indicators.aspx

Côté I.M., Gill J.A., Gardner T.A. and Watkinson A.R. 2005. Measuring coral reef decline through meta-analysis. Phil. Trans. R. Soc. Lond. B. 360: 385–395.

Danielsen F., Balete D.S., Poulsen M.K., Enghoff M., Nozawa C.M. and Jensen A.E. 2000. A simple system for monitoring biodiversity in protected areas of a developing country. Biodivers. Conserv. 9: 1671–1705.

Danielsen F., Mendoza M.M., Alviola P., Balete D.S., Enghoff M., Poulsen M.K. and Jensen A.E. 2003a. Biodiversity monitoring in developing countries: what are we trying to achieve? Oryx 37: 407–409.

Danielsen F., Mendoza M.M., Tagtag A., Alviola P., Balete D.S., Enghoff M., Poulsen M.K. and Jensen A.E. 2003b. On participatory biodiversity monitoring and its applicability – a reply to Yoccoz et al. and Rodríguez. Oryx 37: 412.

Danielsen F., Jensen A.E., Alviola P.A., Balete D.S., Mendoza M.M., Tagtag A., Custodio C. and Enghoff M. 2005. Does monitoring matter? A quantitative assessment of management decisions from locally-based monitoring of protected areas. Biodivers. Conserv. 14: 2633–2652.

Darwall W.R.T. and Dulvy N.K. 1996. An evaluation of the suitability of non-specialist volunteer researchers for coral reef fish surveys. Mafia Island, Tanzania: A case study. Biol. Conserv. 78: 223–231.

Dubois O. and Lowore J. 2000. The Journey Towards Collaborative Forest Management in Africa: Lessons Learned and Some Navigational Aids. IIED Forestry and Land Use series 15. IIED, London, UK, 110 pp.

Engel S.R. and Voshell J.R. 2002. Volunteer biological monitoring: can it accurately assess the ecological condition of streams? Am. Entomol. 48: 164–177.

Ericsson G. and Wallin K. 1999. Hunter observations as an index of moose *Alces alces* population parameters. Wildlife Biol. 5: 177–185.

European Council 2001. Presidency Conclusions, Goteburg Council, 15 and 16 June 2001. SN/200/1/01 REV1, 8 pp.

Fore L.S., Paulsen K. and O'Laughlin K. 2001. Assessing the performance of volunteers in monitoring streams. Freshwater Biol. 46: 109–123.

Gaidet N., Fritz H. and Nyahuma C. 2003. A participatory counting method to monitor populations of large mammals in non-protected areas: a case study of bicycle counts in the Zambezi Valley, Zimbabwe. Biodivers. Conserv. 12: 1571–1585.

Genet K.S. and Sargent L.G. 2003. Evaluation of methods and data quality from a volunteer-based amphibian call survey. Wildlife Soc. Bull. 3: 703–714.

Gray M. and Kalpers J. 2005. Ranger based monitoring in the Virunga-Bwindi Region of East-Central Africa: a simple data collection tool for park management. Biodivers. Conserv. 14: 2723–2741.

Green R.E., Balmford A., Crane P.R., Mace G.M., Reynolds J.D. and Turner R.K. 2005. A framework for improved monitoring of biodiversity: responses to the World Summit on Sustainable Development. Conserv. Biol. 19: 56–65.

Greenwood J.J.D. 2003. The monitoring of British breeding birds: A success story for conservation science? Sci. Total Environ. 310: 221–230.

Gregory R.D., van Strien A., Vorisek P., Meyling A.W.G., Noble D.G., Foppen R.P.B. and Gibbons D.W. 2005. Developing indicators for European birds. Phil. Trans R. Soc. Lond. B. 360: 269–288.

Hellier A., Newton A.C. and Gaona S.O. 1999. Use of indigenous knowledge for rapidly assessing trends in biodiversity: a case study from Chiapas, Mexico. Biodivers. Conserv. 8: 869–889.

Hockley N.J., Jones J.P.G., Andriahajaina F.B., Manica A., Ranambitsoa E.H. and Randriamboahary J.A. 2005. When should communities and conservationists monitor exploited resources? Biodivers. Conserv. 14: 2795–2806.

Hoyer M.V., Winn J. and Canfield D.E.Jr. 2001. Citizen monitoring of aquatic bird populations using a Florida lake. Lake Reserv. Manage. 17: 82–89.

Hulme D. and Murphree M. 1999. Communities, wildlife and the 'new conservation' in Africa. J. Int. Develop. 11: 277–286.

Janzen D.H. 2004. Setting up tropical biodiversity for conservation through non-damaging use: Participation by parataxonomists. J. Appl. Ecol. 41: 181–187.

Jeanrenaud S. 2002a. Changing people/nature representations in international conservation projects. IDCS Bull. 33: 111–122.

Jeanrenaud S. 2002b. People-orientated Approaches in Global Conservation: Is the Leopard Changing its Spots? Institutionalising Participation Series, IIED, London, UK, 80 pp.

Jenkins M., Green R.E. and Madden J. 2003. The challenge of measuring global change in wild nature: are things getting better or worse? Conserv. Biol. 17: 1–4.

Kapos V., Jenkins M. and Loh J. 2004. Rising to the Biodiversity Challenge. The role of Species Population Trend Indices such as the Living Planet Index in Tracking Progress Towards Global and National Biodiversity Targets. World Bank, Washington, D.C., USA.

Kerr M., Ely E., Lee V. and Mayio A. 1994. A profile of volunteer environmental monitoring: national survey results. Lake Reserv. Manage. 9: 1–4.

Kremen C., Merenlender A.M. and Murphy D.D. 1994. Ecological monitoring: a vital need for integrated conservation and development programs in the tropics. Conserv. Biol. 8: 388–397.

Lawrence A. and Elphick M. 2002. Summary report. In: Lawrence A. and Elphick M. (eds), Policy Implications of Participatory Biodiversity Assessment. ETFRN International Seminar for Policy-Makers and Implementers, London, UK. ETFRN, Environmental Change Institute, Oxford, UK, 33 pp.

Loh J., Green R.E., Ricketts T., Lamoreux J., Jenkins M., Kapos V. and Randers J. 2005. The Living Planet Index: using species population time series to track trends in biodiversity. Phil. Trans. R. Soc. Lond. B. 360: 289–295.

Margoluis R. and Salafsky N. 2001. A guide to threat reduction assessment. Biodiversity Support Program, Washington, DC.

Marks S.A. 1994. Local hunters and wildlife surveys: a design to enhance participation. Afr. J. Ecol. 32: 233–254.

McLaren M.A. and Cadman M.D. 1999. Can novice volunteers provide credible data for bird surveys requiring song identification? J. Field Ornithol. 70: 481–490.
Mumby P.J., Harborne A.R., Raines P.S. and Ridley J.M. 1995. A critical assessment of data derived from Coral Cay Conservation volunteers. Bull. Mar. Sci. 56: 737–751.
NORDECO and DENR 2002. DENR Biodiversity Monitoring System. Implementation Results from Eight Protected Areas January 1999–June 2001, the Philippines. Department of Environment and Natural Resources, Manila, the Philippines, 67 pp.
Noss A.J. 1999. Censusing rainforest game species with communal net hunts. Afr. J. Ecol. 37: 1–11.
Noss A.J., Oetting I. and Cuéllar R.L. 2005. Hunter self-monitoring by the Isoseño-Guaraní in the Bolivian Chaco. Biodivers. Conserv. 14: 2679–2693.
Obura D.O., Wells S., Church J. and Horrill C. 2002. Monitoring of fish and fish catches by local fishermen in Kenya and Tanzania. Mar. Freshwater Res. 53: 215–222.
Penrose D. and Call S. 1995. Volunteer monitoring of benthic macroinvertebrates: regulatory biologists' perspectives. J. North Am. Benthol. Soc. 14: 203–209.
Pomeroy D. 1992. Counting Birds. Technical Handbook No. 6. AWF: African Wildlife Foundation, Nairobi, Kenya.
Poulsen M.K. and Luanglath K. 2005. Projects come, projects go: lessons from participatory monitoring in southern Laos. Biodivers. Conserv. 14: 2591–2610.
van Rijsoort J. and Jinfeng Z. 2005. Participatory resource monitoring as a means for promoting social change in Yunnan, China. Biodivers. Conserv. 14: 2543–2573.
Rodríguez J.P. 2003. Challenges and opportunities for surveying and monitoring tropical biodiversity – a response to Danielsen et al. Oryx 37: 411.
Roberts R.L., Donald P.F. and Fischer I.J. 2005. Wordbirds: developing a web-based data collection system for the global monitoring of bird distribution and abundance. Biodivers. Conserv. 14: 2807–2820.
Roe D. and Jack M. 2001. Stories from Eden: case-studies of community-based wildlife management. IIED Evaluating Eden Series 9. IIED, London, UK, 66 pp.
Royal Society 2003. Measuring Biodiversity for Conservation. Policy Document 11/3. The Royal Society, London, UK.
Schmitt E.F. and Sullivan K.M. 1996. Analysis of a volunteer method for collecting fish presence and abundance data in the Florida Keys. Bull. Mar. Sci. 59: 404–416.
Sheil D. 2001. Conservation and biodiversity monitoring in the tropics: realities, priorities and distractions. Conserv. Biol. 15: 1179–1182.
Sheil D. and Lawrence A. 2004. Tropical biologists, local people and conservation: new opportunities for collaboration. Trends Ecol. Evol. 19: 634–638.
Steinmetz R. 2000. Ecological Surveys, Monitoring and the Involvement of Local People in Protected Areas of Lao P.D.R. IIED Evaluating Eden Series Discussion Paper 13. IIED, London, UK, 38 pp.
Stolton S., Hockings M., Dudley N., MacKinnon K. and Whitten T. 2003. Reporting Progress in Protected Areas: A Site-level Management Effectiveness Tracking Tool. WWF and World Bank, Washington, DC.
Stuart-Hill G., Diggle R., Munali B., Tagg J. and Ward D. 2005. The event book system: a community based natural resource monitoring system from Namibia. Biodivers. Conserv. 14: 2611–2631.
Sutherland W.J., Pullin A.S., Dolman P.M. and Knight T.M. 2004. The need for evidence-based conservation. Trends Ecol. Evol. 19: 305–308.
Ticheler H.-J., Kolding J. and Chanda B. 1998. Participation of local fishermen in scientific fisheries data collection: a case study from the Bangweulu Swamps, Zambia. Fish. Manage. Ecol. 5: 81–92.
Topp-Jørgensen E., Poulsen M.K., Lund J.F. and Massao J.F. 2005. Community-based monitoring of natural resource use and forest quality in montane forests and miombo woodlands in Iringa District, Tanzania. Biodivers. Conserv. 14: 2653–2677.

Townsend W.R., Borman A.R., Yiyoguaje E. and Mendua L. 2005. Cofán Indians' monitoring of freshwater turtles in Zábalo, Ecuador. Biodivers. Conserv. 14: 2743–2755.

United Nations 2000. United Nations Millenium Declaration. General Assembly resolution 55/2.

United Nations Environment Programme 2002. Report on the Sixth Meeting of the Conference of the Parties to the Convention on Biological Diversity (UNEP/CBD/COP/6/20/Part 2) Strategic Plan Decision VI/26.

United Nations Environment Programme 2004. Decisions Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Seventh Meeting (UNEP/CBD/COP/7/21/Part 2) Decision VII/30 (Convention on Biological Diversity, 2004). http://www.biodiv.org/decisions/dfault.aspx?m = COP-07&id = 7767&lg = 0.

Uychiaoco A.J., Arceo H.O., Green S.J., De la Cruz M.T., Gaite P.A. and Aliño P.M. 2005. Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. Biodivers. Conserv. 14: 2775–2794.

Wells M.P. and McShane T.O. 2004. Integrating protected area management with local needs and aspirations. Ambio 33: 513–519.

Wiens J.A. 1989. Spatial scaling in ecology. Functional Ecol. 3: 385–397.

World Bank 1996. Field guides: Useful tools in environmental planning and management. Environ. Dept. Dissemination Notes 51: 1–4.

Yoccoz N.G., Nichols J.D. and Boulinier T. 2001. Monitoring of biological diversity in space and time. Trend Ecol. Evol. 16: 446–453.

Yoccoz N.G., Nichols J.D. and Boulinier T. 2003. Monitoring of biological diversity – a response to Danielsen et al. Oryx 37: 410.

APPENDIX V

Mascia, M.B., Pailler, S., Thieme, M., Rowe, A., Bottrill, M.C., **Danielsen, F**., Geldmann, J., Naidoo, R., Pullin, A. and Burgess, N.D. 2014.
Commonalities and complementarities among approaches to conservation monitoring and evaluation.
Biological Conservation 169: 258–267.

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Biological Conservation 169 (2014) 258–267

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Perspective

Commonalities and complementarities among approaches to conservation monitoring and evaluation

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ARTICLE INFO

Article history:
Received 24 April 2013
Received in revised form 30 October 2013
Accepted 14 November 2013

Keywords:
Ambient monitoring
Management assessment
Performance measurement
Impact evaluation
Systematic review

ABSTRACT

Commonalities and complementarities among approaches to conservation monitoring and evaluation (M&E) are not well articulated, creating the potential for confusion, misuse, and missed opportunities to inform conservation policy and practice. We examine the relationships among five approaches to conservation M&E, characterizing each approach in eight domains: the focal question driving each approach, when in the project cycle each approach is employed, scale of data collection, the methods of data collection and analysis, the implementers of data collection and analysis, the users of M&E outputs, and the decisions informed by these outputs. *Ambient monitoring* measures status and change in ambient social and ecological conditions, independent of any conservation intervention. *Management assessment* measures management inputs, activities, and outputs, as the basis for investments to build management capacity for conservation projects. *Performance measurement* assesses project or program progress toward desired levels of specific activities, outputs, and outcomes. *Impact evaluation* is the systematic process of measuring the intended and unintended causal effects of conservation interventions, with emphasis upon long-term impacts on ecological and social conditions. *Systematic review* examines existing research findings to assess the state of the evidence regarding the impacts of conservation interventions, and to synthesize the insights emerging from this evidence base. Though these five approaches have some commonalities, they complement each other to provide unique insights for conservation planning, capacity-building, adaptive management, learning, and accountability. Ambient monitoring, management assessment, and performance measurement are now commonplace in conservation, but opportunities remain to inform conservation policy and practice more fully through catalytic investments in impact evaluations and systematic reviews.

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http://dx.doi.org/10.1016/j.biocon.2013.11.017

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1. Introduction

Monitoring and evaluation (M&E) has a long history in conservation, with diverse approaches developed for diverse purposes (Stem et al., 2005). In recent years, scholars have advocated M&E as a means to facilitate the wise use of scarce conservation funds (Ferraro and Pattanayak, 2006; Sutherland et al., 2004), respond to the environmental implications of ineffective management (Hockings et al., 2006), promote accountability (Christensen, 2003; Jepson, 2005), and track progress towards broader conservation goals (Gratwicke et al., 2007). These aspirations for widespread and effective use of conservation M&E have become increasingly codified in policy (e.g., DANIDA, 2006; USAID 2011), technical guidance (e.g., Hockings et al., 2006; Kapos et al., 2008; Margoluis and Salafsky, 1998), and practice (Miteva et al., 2012), as scholars, practitioners, and donors have sought to target conservation investments, track progress, foster adaptive management, ensure accountability, and catalyze learning within the conservation sector.

Despite previous reviews (e.g., Birnbaum and Mickwitz, 2009; Kapos et al., 2008; Stem et al., 2005), the commonalities and complementarities among current approaches to conservation M&E are not well articulated. This absence of clarity creates the potential for confusion, misuse, and missed opportunities to inform conservation policy and practice through M&E (Stem et al., 2005). Misuse of M&E tools and approaches poses a number of risks (Oral History Project Team, 2007), including misallocation of M&E resources, unreasonable expectations of M&E activities, inaccurate assessments of conservation interventions, and misguided allocation of conservation resources (Ferraro and Pattanayak, 2006; Stem et al., 2005). If conservation M&E fails to realize its potential because of misuse and missed opportunities, the perceived value of M&E may decline and its use may be limited further. Effective use of M&E, by contrast, may catalyze a virtuous cycle of wider adoption across the conservation community, as predicted by social theories of innovation diffusion (Rogers, 1995).

To foster more effective application of M&E approaches within the conservation sector, we examine commonalities and complementarities among five approaches to conservation M&E: ambient monitoring, management assessment, performance measurement, impact evaluation, and systematic review. We define each approach and characterize each in eight domains: the focal question driving the approach, when in the project cycle the approach is employed, the scale of data collection, the methods of data collection and analysis, the implementers of data collection and analysis, the users of M&E outputs, and the decisions informed by these outputs. We then explore the relationship of these five approaches to established frameworks for conservation planning and analysis, and highlight the implications for conservation science and policy. By providing conservation scholars and practitioners with a framework for understanding the relationships among approaches to conservation M&E, we hope to empower better informed "consumers" and "producers" of M&E.

2. Concepts and terminology

The abundance of jargon, much of it ill-defined, contributes to confusion regarding conservation M&E. In this analysis, we adhere to the concepts and terminology within the established literature on program evaluation (Table 1), as studied and practiced by members of the American Evaluation Association (www.eval.org). *Monitoring* is an ongoing function that systematically collects data on specified indicators, whereas *evaluation* is the systematic and objective assessment of an ongoing or completed project, program, or policy, often in order to determine the merit or worth of the intervention (DAC, 2002). (*Merit* is the impact attributable to the intervention; *worth* is the value of these changes to decisionmakers and key stakeholders.) The distinctions among *inputs*, *activities*, *outputs*, *outcomes,* and *impacts* allow clear differentiation among approaches to conservation M&E (below). Similarly, *projects*, *programs*, and *policies* represent distinct scales of human action at which conservation M&E may occur. Some approaches to conservation M&E strive to document and measure progress against an intervention's *theory of change*, which articulates and graphically illustrates the assumed logical and causal relationship between an intervention and its anticipated outcomes (Weiss, 1995). Of the five approaches to conservation M&E that we examine, impact evaluation and systematic review attempt to explicitly test or examine the validity of these theories of change. Ambient monitoring, management assessment, and performance measurement, by contrast, do not explicitly test – and often assume – the validity of the underlying program logic (i.e., implementation of an intervention will lead to desired outcomes).

3. Approaches to conservation M&E

3.1. Ambient monitoring

Focal question: What is the state of ambient social and/or environmental conditions, and how are these conditions changing over time and space?

Ambient monitoring is the process of systematically observing the state of social and/or environmental conditions over time, independent of any conservation intervention. Sometimes referred to as "status assessment" (Stem et al., 2005) or "surveillance monitoring" (Nichols and Williams, 2006), *ambient monitoring is not intended to measure the attributes or consequences of conservation interventions*, but, rather, to characterize the broader social and ecological context within which conservation occurs. Depending upon the spatial and temporal scale of ambient monitoring, *however, data derived from ambient monitoring efforts can be repurposed to inform M&E efforts that directly examine conservation interventions*. Ambient monitoring may measure variables such as human demography (e.g., Hobbs and Stoops, 2002), human health (e.g., ZIMSTAT and ICF, 2012), patterns of natural resource use and other human behaviors (e.g.,

Table 1
Definitions of key concepts in conservation monitoring and evaluation.

Monitoring[a]	An ongoing function that systematically collects data on specified indicators
Evaluation[a]	The systematic and objective assessment of an ongoing or completed project, program, or policy, often in order to determine the merit or worth of the intervention
Input[a]	The financial, human, and material resources used for an intervention
Activity[a]	Actions taken or work performed through which inputs are mobilized to produce specific outputs
Output[a]	The products, goods, and services that result from an intervention
Outcome[a]	The desired ends that intervention outputs are intended to induce (i.e., changes in knowledge and attitudes, behaviors, and/or social and environmental conditions)
Impact[a]	The intended and unintended consequences (i.e., changes in knowledge and attitudes, behaviors, and/or social and environmental conditions) that are directly or indirectly caused by an intervention
Project[b]	A discrete set of planned activities collectively trying to achieve a specific outcome or set of outcomes, often as a component of a program and as a manifestation of a policy
Program[b]	A suite of projects collectively organized to achieve a specific outcome or set of outcomes, often serving as a tactical means of achieving policy ends
Policy[c]	A broad or strategic statement of intent to accomplish specific aims, often implemented through one or more programs
Intervention[a]	Specific action (project, program, or policy) designed to effect a specific desired change; may be manifestation of broader strategy
Theory of change[d]	An articulation and frequently graphical illustration of the assumed logical, causal relationships between intervention (project, program, policy) inputs, activities, outputs, and outcomes

[a] Definitions adapted from DAC (2002).
[b] Definition adapted from Bartlett (1994).
[c] Definition adapted from Brewer and DeLeon (1983).
[d] Definition adapted from Weiss (1995). Sometimes referred to as a *logic model*, *logframe*, *logical framework approach*, or *results chain*.

Ticheler et al., 1998), wildlife population size (e.g., Mysterud et al., 2007), and the condition of important habitats (e.g., Hansen et al., 2008). Government censuses of human populations, which date to perhaps the 16th century B.C. (Missiakoulis, 2010), were likely the first formal attempts at ambient monitoring; farmers, fishers, and forest users have informally monitored resource conditions for even longer, their observations influencing survival strategies and resource use (Danielsen et al., 2000). Formal ecological monitoring initially focused on monitoring populations of various species over time. For instance, on the basis of fish catch records, Bertram documented the (declining) population of inshore Scottish herring *Clupea harengus* in the 19th century (Bertram, 1865). Methods for ambient monitoring have since diversified and become more sophisticated (Gardner, 2010).

Ambient monitoring provides valuable information for conservation planning and priority-setting, complementing knowledge of history, culture, political dynamics, and other contextual factors. Information regarding spatial patterns and temporal trends in the status of social and ecological conditions helps conservation decisionmakers to identify locations for future conservation interventions, to set priorities among these locations, and to set management targets for these sites (Gardner et al., 2008; Stephanson and Mascia, in press; Yoccoz et al., 2001). Ambient monitoring data also helps decisionmakers to identify socially and ecologically appropriate interventions in a given location (Funder et al., 2013; Stephanson and Mascia, in press). Ambient monitoring may also provide the data required to explore socio-ecological relationships and, as the social and ecological context for conservation shifts, foster adaptive management (Stephanson and Mascia, in press). Thus, in a landscape context, ambient monitoring data from a national census and an ecoregional forest monitoring program could help conservation decisionmakers to (a) identify priority sites for conservation interventions; (b) choose among potential strategies (e.g., national parks v. community forests) in these locations; (c) understand the dynamic relationship between human populations and forest cover; and (d) revisit conservation strategies as human populations and forest cover change with time.

Ambient monitoring provides information relevant to decision making across scales, informing senior decisionmakers and local resource users alike. However, ambient monitoring can be difficult or expensive to undertake (Gardner et al., 2008; Nichols and Williams, 2006; Stem et al., 2005). Locally-based ambient monitoring schemes, when properly designed and carefully tailored to local issues, provide a low-cost alternative that simultaneously builds capacity among local constituents (Danielsen et al., 2005). Such locally-based monitoring schemes may prompt practical and effective management interventions by increasing the speed of decision-making and by providing information to address environmental problems at operational scales of management (Danielsen et al., 2010). More generally, novel methods of participatory monitoring (e.g., crowd-sourcing data) present opportunities for citizen science to expand monitoring of social and ecological conditions (Dickinson et al., 2010).

3.2. Management assessment

Focal question: What are the management inputs, activities, and outputs associated with a conservation intervention, and how are these changing over time?

Management assessment is the process of measuring the management inputs, activities, and outputs associated with a conservation intervention, in order to identify management strengths, weaknesses, and needs (e.g., NOAA, 2011). Management assessments are not linked to specific performance goals or an explicit program logic, but are instead predicated on the assumption that conservation interventions with sufficient management capacity and appropriate activities are more likely to deliver positive conservation outcomes than interventions with low capacity and misaligned activities (Ervin, 2003; Leverington et al., 2010a). Thus, management assessments allow one to know if an intervention is "well-managed" (i.e., has a robust management presence on the ground) or exists solely on paper (e.g., "paper park"). Management assessments originated in the late 1990s, when it became clear that (a) declaration of protected areas did not necessarily result in adequate management inputs, and (b) biodiversity was declining, despite the increasing number and spatial extent of protected areas (Ervin, 2003; Hockings and Phillips, 1999). Today, management assessments are still primarily employed by governments and international organizations to assess protected areas and protected area systems (NOAA, 2011; Stolton et al., 2007), though this approach is applicable to other conservation interventions. (Management assessment is distinct from "management effectiveness evaluation" and its associated tools, though data generated by the latter are often used to assess the adequacy of management inputs, activities, and outputs [see Discussion]).

Management assessments vary in complexity, but the most commonly used methods are relatively fast, simple, and inexpensive to implement (e.g., NOAA, 2010, 2011). Management assessments often employ a standardized, self-administered questionnaire to measure intervention inputs (e.g., funding, personnel), activities (e.g., enforcement, boundary demarcation), and outputs (e.g., management plans, regulations) (Ervin, 2003; NOAA, 2011; Stolton et al., 2007). Project managers usually complete the self-administered questionnaires and then compile the results using a

standardized scorecard; information requirements for such management assessments are typically modest, and largely rely on (a) accessible information that is available on site and (b) the knowledge of those undertaking day-to-day management (Cook and Hockings, 2011). Because management assessments are generally self-administered by project managers, scholars have questioned the validity and comparability of the resultant data (Cook and Hockings, 2011; Stoll-Kleemann, 2010). At the same time, self-assessment are perhaps more likely to foster clarification of management objectives, use of qualitative data that might otherwise be overlooked, and the integration of results into management decisions (Cook and Hockings, 2011).

To promote public reporting and transparency, many donors include management assessment as a mandatory component of protected area M&E (e.g., Global Environment Facility, World Bank, Critical Ecosystem Partnership Fund). Management assessments have been used in more than 6200 protected areas around the world (Leverington et al., 2010a), and are increasingly being used to assess national and international management and conservation strategies (e.g., Butchart et al., 2010; Pavese et al., 2007; Quan et al., 2011). Despite these M&E investments, it remains unclear whether "well-managed" interventions lead to more successful conservation, since (a) management assessments do not directly measure biodiversity or human well-being, and (b) researchers have not yet widely tested the assumption that protected area inputs, activities, and outputs foster positive conservation impacts (but see Nolte and Agrawal, 2013; Nolte et al., 2013).

3.3. Performance measurement

Focal question: To what extent is a conservation intervention making progress toward its specified objectives for activities, outputs, and outcomes?

Performance measurement is the process of measuring progress toward specified project, program, or policy objectives, including desired levels of activities, outputs, and outcomes (DAC, 2002). Sometimes referred to as "performance monitoring" (Rich, 1998) or "performance evaluation" (USAID, 2011), performance measurement rose to prominence in the 1980s and early 1990s, as governments and private sector actors responded to a perceived need for greater accountability regarding the performance of public and private sector program investments in education, public health, social services, and other fields (Rich, 1998; Wholey, 1997). The conservation sector was a relative latecomer to performance measurement, with concerted efforts widely implemented only since the 1990s (Stem et al., 2005). Government agencies, nongovernmental organizations (NGOs), and academia subsequently developed numerous performance measurement methodologies (e.g., Kapos et al., 2008; Margoluis and Salafsky, 1998; UNDP/GEF, 2005). Though the term "performance measurement" has sometimes been used interchangeably with "performance-based," "results-based," or "outcomes-based" management, we follow Wholey (1996) in recognizing performance *measurement* as a mechanism to provide information necessary for *management* (i.e., decisionmaking).

Performance measurement tracks the progress of a single project or program over time against intended levels of accomplishment, in order to provide managers, organizational leadership, donors, and the public with information about project or program performance. Indicators are defined to track progress along a theory of change, toward both interim objectives (e.g., activities completed, policies changed, threats diminished) and ultimate objectives or goals (e.g., improved status of a species or ecosystem, enhanced human well-being). Tensions exist among rigor, simplicity, and cost-effectiveness when identifying data collection methods and analyses for performance measurement (Margoluis et al., 2009), particularly for outcome indicators that may be difficult to measure reliably or precisely via expert judgment or existing secondary sources (Cook et al., 2010). Because performance measurement usually relies heavily upon existing information and expert judgment, it is often relatively inexpensive and does not require specialized expertise or complex research design. More intensive performance measurement efforts (e.g., primary data collection, attention to confounding variables) require greater expertise and financial investments, but may provide greater certainty and precision.

Performance measurement is widely applied among governmental and nongovernmental conservation organizations to monitor project progress, inform adaptive management, and foster reporting and accountability. Performance measurement thus provides useful information to managers, especially where financial and human capacities are limited. The findings derived from performance measurement are overstated, however, by those who would attribute observed changes in outcome indicators to intervention activities and outputs (Ferraro and Pattanayak, 2006). In fact, because performance measurement approaches do not compare the outcomes of an intervention to a valid counterfactual that isolates the effects of an intervention from the effects of other causal factors (e.g., by monitoring nonintervention comparison groups), performance measurement cannot definitively attribute observed changes in outcome variables to intervention activities and outputs (Rossi et al., 2004). Nonetheless, if indicators along a programmatic theory of change are strategically chosen and clearly defined from the outset, performance measurement provides valuable information regarding the progress of a project or program toward its stated goals and objectives.

3.4. Impact evaluation

Focal question: What intended and unintended impacts are causally induced by a conservation intervention?

Impact evaluation is the systematic process of assessing the causal effects of a project, program, or policy (Gertler et al., 2011). By comparing what actually happened *with* an intervention to what would have happened *without* it (i.e., the counterfactual), impact evaluations measure the intended and unintended consequences attributable to a (conservation) intervention (Gertler et al., 2011). In addition to providing evidence regarding positive and negative impacts, well-designed impact evaluations may provide insights into the variation in impacts within and among groups, the attributes of an intervention that foster positive (or negative) impacts, and the contexts in which an intervention is most likely to succeed (or fail) (Miteva et al., 2012). Impact evaluations often employ experimental research designs (i.e., random assignment to treatment and non-treatment groups) or quasi-experimental research designs (i.e., statistical identification of appropriate comparison groups); differences in observed changes between the treatment group and non-treatment comparison group represent the impact of the intervention (Rossi et al., 2004). Other research designs are also employed in impact evaluation (e.g., statistical analyses of observational data, in-depth case studies), "though the credibility of their estimates of program effects relies on how well the studies' designs rule out competing causal explanations" (GAO, 2009, p. 1). Impact evaluation has a strong grounding in the field of economics, with widespread use in the health, education, and development sectors (Patton, 2008). Interest in impact evaluation *per se* emerged within the conservation sector in the mid-2000s (e.g., Ferraro and Pattanayak, 2006), spurring an increasing number of impact evaluations from government agencies, NGOs, and universities (Miteva et al., 2012). Recent impact evaluations have examined the impacts of protected areas on forest fires (Nelson and Chomitz, 2011), recovery planning on

Table 2
Commonalities and complementarities among five approaches to conservation monitoring and evaluation. Table reflects most common characteristics of each approach, but exceptions do occur and, in practice, scholars and practitioners sometimes mix or integrate approaches.

	Ambient monitoring	Management assessment	Performance measurement	Impact evaluation	Systematic review
Focal question	What is the state of ambient social and/or environmental conditions, and how are these conditions changing over time and space?	What are the management inputs, activities, and outputs associated with a conservation intervention, and how are these changing over time?	To what extent is a conservation intervention making progress toward its intended objectives for activities, outputs, and outcomes?	What intended and unintended impacts are causally induced by a conservation intervention?	What is the state of the evidence for the impact of an intervention, and what does this evidence say about intervention impacts?
Timing	Varies; often pre-intervention	During implementation	During and after implementation	Post-implementation, with pre-implementation baseline	Post-implementation
Scale	Any; often state/province (social), landscape, ecoregion (ecological), or country (both)	One or more interventions, usually protected areas	Single project or program	Multiple projects or one or more programs, with corresponding nonintervention comparison group	Multiple projects, programs, or policies
Implementer	Professional researchers, citizen volunteers	Project and program managers, government agencies	Project managers	Professional researchers and evaluators	Professional researcher
Decisions supported	Spatial and temporal priority-setting, selection of strategies and objectives	Setting priorities among potential capacity-building investments at one or more projects	Program reporting & accountability assessments; Adapt activities & strategies to enhance performance	Adaptive management of existing and future interventions, scaling up or down future investments in said intervention	Selecting an intervention; scaling up or scaling down investments in said intervention
Practitioner audience	Decision makers at local to global levels	Project and program managers, donors, senior decisionmakers	Project & program managers, donors, senior decisionmakers	Project and program managers, senior decisionmakers, donors	Project and program managers, senior decision makers, donors
Data collection methods	Primary data collection; remote sensing, transects (ecological); household surveys, focus groups (social)	Expert judgment, secondary sources	Expert judgment, secondary sources, occasional primary data	Primary data collection or manipulation of secondary source data; remote sensing, transects (ecological); household surveys, focus groups, interviews (social)	Data extraction from secondary sources
Data analysis	Moderate to complex; may require data processing and statistical analyses	Simple; requires scoring self-administered questionnaires	Simple to moderate; may require statistical manipulation of secondary source data	Complex; requires data management and sophisticated statistical analyses	Moderate to complex; requires sophisticated data extraction and statistical analyses

the status of endangered species (Bottrill et al., 2011), and communal conservancies on human well-being (Glew, 2012).

Impact evaluations inform decisions associated with curtailing, reforming, and expanding (conservation) initiatives (Gertler et al., 2011). Accordingly, the use of impact evaluations is most appropriate with fully implemented programs or interventions, where the goals and activities of the initiative have been defined, and where potential users of the evaluation are identified and prospects for use are strong (GAO, 2009). For emerging or contested interventions, where the theory of change that links interventions to impacts remains unproven, impact evaluation may have particularly high policy relevance and prospects for use by decisionmakers (Gertler et al., 2011; Patton, 2003, pp. 219–220). Experimental and quasi-experimental impact evaluations are most easily employed (a) when it is possible to maintain separation between the treated and untreated populations; (b) where the causal factors that link interventions to impacts are understood and can be measured; and (c) where a good counterfactual can be identified and necessary data obtained (Ferraro, 2009; GAO, 2009). Since real-world conservation settings often possess unique or rare characteristics, which vary by setting and intervention, opportunities for effective use of experimental and quasi-experimental approaches may be limited (Ferraro, 2009; Margoluis et al., 2009). In addition, impact evaluation – especially experimental and quasi-experimental methods – requires substantial expertise, can be costly to implement, and is not always possible for ethical, logistical, or legal reasons (Ferraro and Pattanayak, 2006; GAO, 2009). Given these constraints, impact evaluation is best employed selectively, in appropriate situations where the additional rigor of impact evaluation is required to inform major policy or program decisions (GAO, 2009; Gertler et al., 2011).

3.5. Systematic review

Focal question: What is the state of the evidence for the impacts of a conservation intervention and what does this evidence say about intervention impacts?

Systematic review is a structured process that collates, appraises, and synthesizes all available empirical evidence of relevance to a specific research question (Pullin and Knight, 2009), facilitating the conversion of scientific knowledge into (conservation) practice (Pullin and Knight, 2001, 2009; Stevens and Milne, 1997). At its simplest, evidence synthesis can take the form of a literature review of two or more studies, but the gold standard methodology is systematic review, which attempts to maximize transparency and objectivity (minimizing bias) in capturing and critically appraising all relevant studies. Systematic review for evidence synthesis began in the 1980s, when clinical medicine sought to interpret and translate the findings from many individual studies to inform decisions on which interventions might be most effective for any given medical problem (Pullin and Knight, 2001). First proposed for conservation by Pullin and Knight (2001), the approach is now relatively widespread in the health sector and is also used in the fields of education, social services

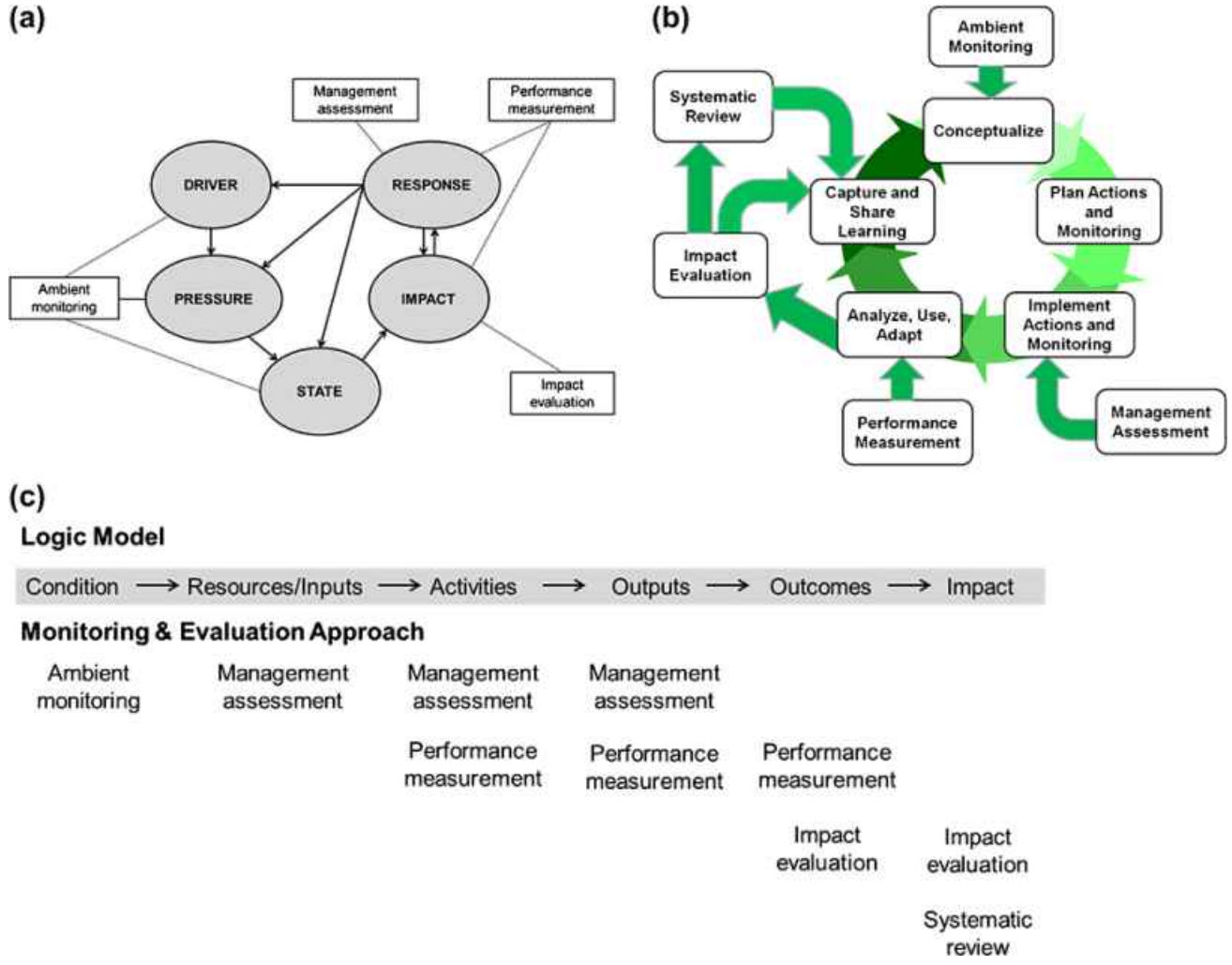

Fig. 1. Relationship between ambient monitoring, management assessment, performance measurement, impact evaluation, and systematic review and three common frameworks for conservation planning and analysis. The Drivers–Pressures–State–Impact–Response (DPSIR) framework (a) elucidates the relationships among *Drivers*, human activities that exert *Pressure* on the environment and, as a consequence, may change the *State* of the environment and society; these *Impacts* may elicit societal *Responses* that address these factors (Smeets and Weterings, 1999). The conservation project cycle (b) begins with an initial *conceptualization* phase, followed by *planning*, *implementation*, *analysis and adaptation*, and *learning* (CMP, 2007). The program logic model (c) articulates the hypothesized causal links between project or program inputs, activities, outputs, outcomes, and impacts (Kellogg Foundation, 2004).

and environmental management, and international development (Petticrew, 2001). Recent systematic reviews in conservation have examined the evidence for engineered structures on salmonid abundance (Stewart et al., 2009a), community forest management on biodiversity and poverty (Bowler et al., 2012), and the conservation impacts of temperate marine protected areas (Stewart et al., 2009b).

Systematic review contributes to a shared evidence base for decisionmakers, addressing questions concerning whether an intervention works or not, and its degree of impact (Pullin and Knight, 2001, 2009). Systematic reviews characterize the state of the evidence by gathering together and describing diverse sets of data generated by studies with contrasting designs, which is particularly useful for achieving consensus when studies have conflicting findings. Systematic review is, thus, most useful when (a) an intervention has been widely and independently applied to achieve a specific goal and (b) multiple well-designed studies of the intervention's effectiveness or impact exist. Systematic review is less suitable where studies and data are few, since data limitations increase the risk of arriving at null or faulty conclusions. In the absence of a robust scientific literature, systematic reviews can highlight knowledge gaps and inform research priorities (e.g., Bowler et al., 2012).

Systematic reviews are normally conducted by an independent review team that combines subject matter experts with review and synthesis experts (CEE, 2010). Systematic reviews require significant resources, time, and technical expertise (CEE, 2010). Though systematic reviews are standard in other sectors, they have not been widely used in conservation, despite their potential (but see www.environmentalevidence.org). Moreover, processes are needed to integrate evidence from systematic reviews into useful policy guidance (Segan et al., 2011). Government agencies and NGOs are beginning to commission systematic reviews to help meet their evidence needs and inform decision making (e.g., Bowler et al., 2012). With an increase in the number of studies that measure the impacts of conservation interventions, opportunities for systematic review and its application to conservation policy will grow commensurately.

4. Discussion

4.1. Conservation M&E in theory

Though ambient monitoring, management assessment, performance measurement, impact evaluation, and systematic review

share some methodological commonalities, these five approaches to conservation M&E address distinct questions and inform distinct policy decisions (Table 2). These five approaches are employed at different points in the project/program cycle (CMP, 2007); examine different aspects of the drivers, pressures, states, impacts, and responses that constitute the relationship between people and the environment (Smeets and Weterings, 1999); and assess distinct components of an intervention (Kellogg Foundation, 2004; Fig. 1). These complementarities can lead to productive synergies, such as when ambient monitoring data are resampled and repurposed to document impacts through impact evaluation, or when impact evaluation and perhaps performance measurement provide the evidence necessary for systematic reviews.

The five approaches we examined do not represent the full range of approaches to conservation M&E. Impact assessment – the *ex ante* estimation of likely ecological and social impacts of proposed future public or private sector activities – is widely employed in conservation and environmental management (Stem et al., 2005). Similarly, both spatial and strategic conservation planning (CMP, 2007; Margules and Pressey, 2000; Pressey and Bottrill, 2009) sometimes act as forms of formative evaluation (i.e., evaluative activities intended to guide program improvement (Rossi et al., 2004; Scriven, 1991)). Needs assessment is an additional, distinct approaches to M&E (Rossi et al., 2004), though it is less commonly applied in conservation.

Similarly, "management effectiveness evaluation" is a concept widely discussed and applied by conservation practitioners (Hockings et al., 2006; Leverington et al., 2010b). As defined by Hockings et al. (2006, pp. 12–13), "management effectiveness evaluation" examines the context, planning, inputs, processes (i.e., activities), outputs, and outcomes of a protected area, a framework for evaluating protected areas that largely mirrors conventional definitions of program evaluation writ large. Examining the site-specific context for an intervention, for example, is characteristic of needs assessment; intervention inputs, activities, and outputs are the typical focus of management assessment, performance measurement, and formative evaluation; and outcomes are principally the domain of impact evaluation. The primary focus of "management effectiveness evaluation" is rarely effectiveness in the conventional sense of the term (i.e., outcomes or impacts; Table 3) (Cook and Hockings, 2011; Leverington et al., 2010b, p. 3).

Additional concepts from the field of program evaluation provide further clarity to our understanding of conservation M&E. The academic literature on program evaluation distinguishes between *formative* and *summative* evaluation, emphasizing not only what is measured but also the relationships among actors and the means by which findings are interpreted and used. *Formative evaluation* is the systematic examination of the ongoing success of an intervention and its processes, which can provide information, insights, and advice about how these can be improved (Rossi et al., 2004; Scriven, 1991). Formative evaluation is generally conducted throughout an intervention, in order to assure continual improvement in efficacy, relevance, logic, and efficiency, and to facilitate ongoing adjustments as the intervention matures (Scriven, 1991). Data collection methods include literature reviews, focus groups, structured surveys, interviews, and direct observation of inputs, activities, outputs, and outcomes. Management assessment and performance measurement address aspects of formative evaluation, particularly those aspects that involve monitoring inputs, activities, and outputs and modifying activities accordingly to improve program performance. In some situations, impact evaluation may serve as a form of formative evaluation (Scriven, 1991). Effective formative evaluation involves decision-makers and stakeholders to ensure that the evaluation is salient and legitimate, and that the findings and recommendations feed into the program cycle (Patton, 2003; Scriven, 1991). Though management assessment and performance measurement provide useful insights for program improvement, they do not answer important questions such as "What is the relevance of this intervention to stakeholders?" or "How do we promote uptake and incorporation of recommendations?" Formative evaluation provides tools to engage stakeholders, complete the program feedback loop, and assure continued relevance of the intervention.

Table 3
Measurement foci of two assessment tools commonly associated with "management effectiveness evaluation:" Management effectiveness tracking tool (METT) and rapid assessment and prioritization of protected areas management (RAPPAM).

Assessment tool	Object of inquiry	# Questions	% Total
METT[a]	Context	1	3.3
	Planning	7	23.3
	Inputs	8	26.7
	Process	11	36.7
	Outputs	1	3.3
	Outcomes	2	6.7
	Total	30	100.0
RAPPAM[b]	Background information	8	5.3
	Pressures & threats	24	15.8
	Context	20	13.2
	Vulnerability	10	6.6
	Planning	15	9.9
	Inputs	20	13.2
	Processes	15	9.9
	Outputs	10	6.6
	Protected area system level	10	6.6
	Protected area policies	10	6.6
	Policy environment	10	6.6
	Total	152	100.0

[a] Based on categorization in Stolton et al. (2007). In addition, the METT includes approximately 30 background questions and 50 contextual questions about pressures and threats that are not considered part of the formal METT assessment process.
[b] Based on categorization in Ervin (2003).

Summative evaluation judges the merit and worth of an intervention (Scriven, 1996). Summative evaluation typically occurs in the final stages of an intervention, to decide whether to continue, discontinue, or expand the intervention (Scriven, 1991). Summative evaluation uses many methods, including empirical experiments, cost-beneft analysis, case studies, interrupted time series, program theory methods, and meta-analysis. Whereas impact evaluation and systematic review similarly document impacts attributable to an intervention, these two approaches to conservation M&E do not generally examine questions related to the value of these impacts to stakeholders and decisionmakers.

4.2. Conservation M&E in practice

The practice of conservation M&E starts by defining the "research" question that will guide data collection, analysis, and use (Fig. 2). The subject of evaluation, the type of knowledge desired, and the intended use for results all inform the development of evaluative questions (Rossi et al., 2004). Once the question has been defined, it is possible to identify the appropriate M&E approach and, subsequently, the appropriate scope, methods, and tools. These choices will also be influenced by the evaluators' information needs, as well as resource and timing limitations. Matching the appropriate M&E approach to the evaluation question, and context, fosters clear expectations about what will be measured, how it will be measured, and the insights for conservation policy and practice that are likely to emerge as a result.

Ambient monitoring, management assessment, performance measurement, impact evaluation, and systematic review each address complementary questions and inform complementary policy

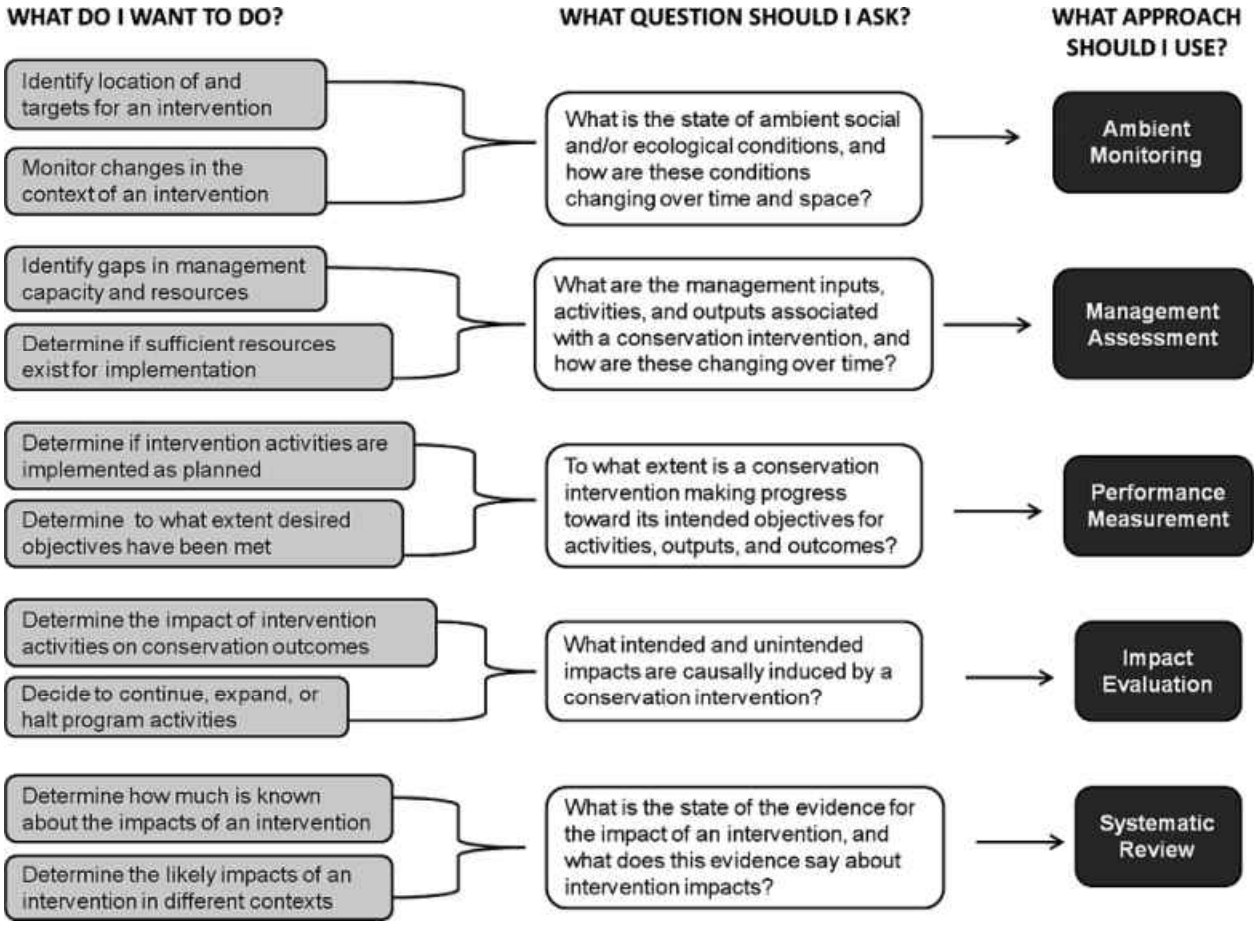

Fig. 2. Decision tree highlighting common information needs in conservation, and the question and approach to monitoring and evaluation that can best respond to those information needs.

decisions, but use of these five approaches to conservation M&E has varied. Ambient monitoring and performance measurement are ubiquitous, and management assessment is commonly applied to protected areas around the world. Impact evaluations and systematic reviews are growing in number, but remain uncommon (Miteva et al., 2012; Segan et al., 2011). Why are some approaches used more widely than others?

Though an approach to M&E is ideally selected in accordance with the focal question, M&E is also influenced by information needs, financial resources, timing, and human capacity. In many conservation settings, resources, time, and expertise are often constrained (Bruner et al., 2004; Gardner et al., 2008; Nichols and Williams, 2006). Management assessment and performance measurement, by design, are useful M&E approaches in resource-constrained contexts, providing valuable information quickly at a low cost, albeit with less rigor and certainty. Ambient monitoring, impact evaluation, and systematic review, on the other hand, require substantial time, expertise, and financial investments, which are not always readily available. Yet the longstanding tradition and diverse contributions of ambient monitoring (often beyond the conservation sector) frequently ensure continued investments despite its cost, time, and expertise requirements.

Incentives also influence the selection of an approach to conservation M&E. Donors and conservation decisionmakers often prioritize and provide financial resources for information gathered within the scope of a project (InterAction, 2010), neglecting alternatives. As a result, M&E is often conducted only within the timeframe of an intervention (i.e., rarely post-project); with existing (and often few) resources; and with data only from within the project area (ignoring conditions at comparison sites outside of the intervention) (Ferraro and Pattanayak, 2006). Program or project implementers may also perceive conservation M&E as an unwanted diversion of scarce resources, a threat to their activities, or simply as an exercise unlikely to add inform or advance conservation policy and practice (Ferraro and Pattanayak, 2006). These factors currently limit opportunities for impact evaluations and subsequent systematic reviews.

5. Conclusions

As the conservation community enters its third decade since the Rio Convention of 1992, ambient monitoring, management assessment, performance measurement, impact evaluation, systematic review, and other approaches to conservation M&E each have complementary roles to play in advancing more informed conservation policies and practices. In the years ahead, greater human capacity, financial investments, and organizational incentives for conservation M&E will be required, especially to generate the impact evaluations and systematic reviews that will enable us to better understand what works, what does not, and why. Knowledge alone, however, will not ensure that the conservation community replicates successes, reforms failures, and avoids repeating the mistakes of the past. Effectively addressing the enduring challenge of biodiversity conservation will require a transformation of conservation policy and practice, through integrated investments in

conservation M&E that advance knowledge, inform policy, build evaluation capacity in the developed and developing world, and catalyze a culture of evidence-based decisionmaking.

Acknowledgements

We thank K. Haisfield for her help compiling this diverse literature, and L. Glew, E. McKenzie, R. Krithivasan, P. Ferraro, and two anonymous reviewers for valuable feedback. Financial support was provided by the Kathryn S. Fuller Science for Nature Fund.

References

Bartlett, R.V., 1994. Evaluating environmental policy success and failure. In: Vig, N.J., Kraft, M.E. (Eds.), Environmental Policy in the 1990s. Congressional Quarterly Press Inc., Washington, DC, pp. 167–187.
Bertram, J.G., 1865. The Harvest of the Sea: A Contribution to the Natural and Economic History of the British Food Fishes. John Murray, London.
Birnbaum, M., Mickwitz, P., 2009. Environmental program and policy evaluation: addressing methodological challenges. New Directions for Evalution 2009, 1–112.
Bottrill, M.C., Walsh, J.C., Watson, J.E.M., Joseph, L.N., Ortega-Argueta, A., Possingham, H.P., 2011. Does recovery planning improve the status of threatened species? Biological Conservation 144, 1595–1601.
Bowler, D.E., Buyung-Ali, L.M., Healey, J.R., Jones, J.P.G., Knight, T.M., Pullin, A.S., 2012. Does community forest management provide global environmental benefits and improve local welfare? Frontiers in Ecology and the Environment 10, 29–36.
Brewer, G.D., deLeon, P., 1983. The Foundations of Policy Analysis. Dorsey Press, Homewood, Illinois.
Bruner, A.G., Gullison, R.E., Balmford, A., 2004. Financial costs and shortfalls of managing and expanding protected-area systems in developing countries. BioScience 54, 1119–1126.
Butchart, S.H.M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.-F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Morcillo, M.H., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vie, J.-C., Watson, R., 2010. Global biodiversity: indicators of recent declines. Science 328, 1164–1168.
CEE (Collaboration for Environmental Evidence), 2010. Guidelines for Systematic Review in Environmental Management. Collaboration for Environmental Evidence. University of Bangor, Bangor, Wales.
Christensen, J., 2003. Auditing conservation in an age of accountability. Conservation in Practice 4, 12–18.
CMP (Conservation Measures Partnership), 2007. Open Standards for the Practice of Conservation, Version 2.0, Conservation Measures Partnership, Washington, DC, p. 39.
Cook, C.N., Hockings, M., 2011. Opportunities for improving the rigor of management effectiveness evaluations in protected areas. Conservation Letters 4, 372–382.
Cook, C.N., Wardell-Johnson, G., Keatley, M., Gowans, S.A., Gibson, M.S., Westbrooke, M.E., Marshall, D.J., 2010. Is what you see what you get? Visual vs. measured assessments of vegetation condition. Journal of Applied Ecology 47, 650–661.
DAC (Development Assistance Committee Working Party on Aid Evaluation), 2002. Glossary of Key Terms in Evaluation and Results Based Management. Organisation for Economic Co-operation and Development, Paris.
DANIDA (Danish International Development Agency), 2006. Evaluation Guidelines. Ministry of Foreign Affairs of Denmark, Copenhagen.
Danielsen, F., Balete, D.S., Poulsen, M.K., Enghoff, M., Nozawa, C.M., Jensen, A.E., 2000. A simple system for monitoring biodiversity in protected areas of a developing country. Biodiversity and Conservation 9, 1671–1705.
Danielsen, F., Burgess, N., Balmford, A., 2005. Monitoring matters: examining the potential of locally-based approaches. Biodiversity and Conservation 14, 2507–2542.
Danielsen, F., Burgess, N.D., Jensen, P.M., Pirhofer-Walzl, K., 2010. Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples involvement. Journal of Applied Ecology 47, 1166–1168.
Dickinson, J.L., Zuckerberg, B., Bonter, D.N., 2010. Citizen science as an ecological research tool: challenges and benefits. Annual Review of Ecology, Evolution, and Systematics 41, 149–172.
Ervin, J., 2003. Rapid Assessment and Prioritization of Protected Area Management (RAPPAM) Methodology. WWF, Gland, Switzerland.
Ferraro, P.J., 2009. Counterfactual thinking and impact evaluation in environmental policy. New Directions for Evaluations 122, 75–84.
Ferraro, P.J., Pattanayak, S.K., 2006. Money for nothing? A call for empirical evaluation of biodiversity conservation investments. PLOS Biology 4, 482–488.
Funder, M., Danielsen, F., Ngaga, Y., Nielsen, M.R., Poulsen, M.K., 2013. Reshaping Conservation: The Social Dynamics of Participatory Monitoring in Tanzania's Community-Managed Forests. Conservation and Society 11, 218–232.
GAO (Government Accountability Office), 2009. Program Evaluation: A Variety of Rigorous Methods Can Help Identify Effective Interventions. U.S. Government Accountability Office, Washington, DC, p. 45.
Gardner, T.A., 2010. Monitoring Forest Biodiversity: Improving Conservation through Ecologically Responsible Management. Earthscan, London.
Gardner, T.A., Barlow, J., Araujo, I.S., Ávila-Pires, T.C., Bonaldo, A.B., Costa, J.E., Esposito, M.C., Ferreira, L.V., Hawes, J., Hernandez, M.I.M., Hoogmoed, M.S., Leite, R.N., Lo-Man-Hung, N.F., Malcolm, J.R., Martins, M.B., Mestre, L.A.M., Miranda-Santos, R., Overal, W.L., Parry, L., Peters, S.L., Ribeiro-Junior, M.A., Da Silva, M.N.F., Da Silva Motta, C., Peres, C.A., 2008. The cost-effectiveness of biodiversity surveys in tropical forests. Ecology Letters 11, 139–150.
Gertler, P.J., Martinez, S., Premand, P., Rawlings, L.B., Vermeersch, C.M.J., 2011. Impact Evaluation in Practice. The World Bank, Washington, DC.
Glew, L., 2012. Evaluating the effectiveness of community-based conservation in northern Kenya, Ph.D. Dissertation, Department of Environmental Science. University of Southampton, Southampton, UK.
Gratwicke, B., Seidensticker, J., Shrestha, M., Vermilye, K., Birnbaum, M., 2007. Evaluating the performance of a decade of Save The Tiger Fund's investments to save the world's last wild tigers. Environmental Conservation 34, 255–265.
Hansen, M.C., Stehman, S.V., Potapov, P.V., Loveland, T.R., Townshend, J.R.G., DeFries, R.S., Pittman, K.W., Arunarwati, B., Stolle, F., Steininger, M.K., Carroll, M., DiMiceli, C., 2008. Humid tropical forest clearing from 2000 to 2005 quantified by using multitemporal and multiresolution remotely sensed data. Proceedings of the National Academy of Sciences 105, 9439–9444.
Hobbs, F., Stoops, N., 2002. Demographic Trends in the 20th Century: Census 2000 Special Reports. U.S. Census Bureau, Washington, DC.
Hockings, M., Phillips, A., 1999. How well are we doing? Some thoughts on the effectiveness of protected areas. Parks 9, 5–14.
Hockings, M., Stolton, S., Leverington, F., Dudley, N., Courrau, J., 2006. Evaluating Effectiveness: A Framework for Assessing Management Effectiveness of Protected Areas, second ed. IUCN, Gland, Switzerland.
InterAction, 2010. Evaluation and Program Effectiveness Working Group, Feedback and Recommendations on USAID's Monitoring and Evaluation Practices. InterAction, Washington, DC.
Jepson, P., 2005. Governance and accountability of environmental NGOs. Environmental Science & Policy 8, 515–524.
Kapos, V., Balmford, A., Aveling, R., Bubb, P., Carey, P., Entwistle, A., Hopkins, J., Mulliken, T., Safford, R., Stattersfield, A., Walpole, M., Manica, A., 2008. Calibrating conservation: new tools for measuring success. Conservation Letters 1, 155–164.
Kellogg Foundation, W.K., 2004. Using Logic Models to Bring Together Planning, Evaluation, and Action: Logic Model Development Guide. W.K. Kellogg Foundation, Battle Creek, Michigan.
Leverington, F., Costa, K., Pavese, H., Lisle, A., Hockings, M., 2010a. A global analysis of protected area management effectiveness. Environmental Management 46, 685–698.
Leverington, F., Lemos Costa, K., Courrau, J., Pavese, H., Nolte, C., Marr, M., Coad, L., Burgess, N., Bomhard, B., Hockings, M., 2010b. Management Effectiveness Evaluation in Protected Areas – A Global Study, second ed. University of Queensland, Brisbane, Australia.
Margoluis, R., Salafsky, N., 1998. Measures of Success: Designing, Managing, and Monitoring Conservation and Development Projects. Island Press, Washington, DC.
Margoluis, R., Stem, C., Salafsky, N., Brown, M., 2009. Design alternatives for evaluating the impact of conservation projects. New Directions for Evalution 122, 85–96.
Margules, C.R., Pressey, R.L., 2000. Systematic conservation planning. Nature 405, 243–253.
Missiakoulis, S., 2010. Cecrops, King of Athens: the first (?) recorded population census in history. International Statistical Review 78, 413–418.
Miteva, D.A., Pattanayak, S.K., Ferraro, P.J., 2012. Evaluation of biodiversity policy instruments: what works and what does not? Oxford Review of Economic Policy 28, 69–92.
Mysterud, A., Meisingset, E.L., Veiberg, V., Langvatn, R., Solberg, E.J., Loe, L.E., Stenseth, N.C., 2007. Monitoring population size of red deer *Cervus elaphus*: an evaluation of two types of census data from Norway. Wildlife Biology 13, 285–298.
Nelson, A., Chomitz, K.M., 2011. Effectiveness of strict vs. multiple use protected areas in reducing tropical forest fires: a global analysis using matching methods. PLoS One 6, e22722.
Nichols, J.D., Williams, B.K., 2006. Monitoring for conservation. Trends in Ecology and Evolution 21, 668–673.
NOAA (National Oceanic and Atmospheric Administration), 2010. Marine Protected Area Management Assessment Checklist. U.S. National Oceanic and Atmospheric Administration, Washington, DC.
NOAA (National Oceanic and Atmospheric Administration), 2011. User's Guide for the NOAA Coral Reef Conservation Program MPA Checklist. U.S. National Oceanic and Atmospheric Administration, Washington, DC.
Nolte, C., Agrawal, A., 2013. Linking management effectiveness indicators to observed effects of protected areas on fire occurrence in the Amazon rainforest. Conservation Biology 27, 155–165.
Nolte, C., Agrawal, A., Barreto, P., 2013. Setting priorities to avoid deforestation in Amazon protected areas: are we choosing the right indicators? Environmental Research Letters 8, 015039.
Oral History Project Team, 2007. The oral history of evaluation, Part 5: An interview with Michael Quinn Patton. American Journal of Evaluation 28, 102–114.

Patton, M.Q., 2003. Utilization-focused evaluation. In: Kellaghan, T., Stufflebeam, D.L. (Eds.), International Handbook of Educational Evaluation: Part One. Kluwer Academic Publishers, Norwood, MA, pp. 223–244.
Patton, M.Q., 2008. Utilization-Focused Evaluation, fourth ed. Sage Publications, Thousand Oaks, California.
Pavese, H.B., Leverington, F., Hockings, M., 2007. Global study of protected areas management effectiveness: the Brazilian perspective. Natureza & Conservacao 5, 152–162.
Petticrew, M., 2001. Systematic reviews from astronomy to zoology: myths and misconceptions. BMJ 322, 98–101.
Pressey, R.L., Bottrill, M.C., 2009. Approaches to landscape- and seascape-scale conservation planning: convergence, contrasts and challenges. Oryx 43, 464–475.
Pullin, A.S., Knight, T.M., 2001. Effectiveness in conservation practice: pointers from medicine and public health. Conservation Biology 15, 50–54.
Pullin, A.S., Knight, T.M., 2009. Doing more good than harm – building an evidence-base for conservation and environmental management. Biological Conservation 142, 931–934.
Quan, J., Ouyang, Z.Y., Xu, W.H., Miao, H., 2011. Assessment of the effectiveness of nature reserve management in China. Biodiversity and Conservation 20, 779–792.
Rich, R.F., 1998. Program evaluation and environmental policy: the state of the art. In: Knaap, G.J., Kim, T.J. (Eds.), Environmental Program Evaluation: A Primer. University of Illinois Press, Chicago, pp. 23–41.
Rogers, E.M., 1995. Diffusion of Innovation, fourth ed. Free Press, New York.
Rossi, P.H., Lipsey, M.W., Freeman, H., 2004. Evaluation: A Systematic Approach, seventh ed. Sage Publications, Thousand Oaks, California.
Scriven, M., 1991. Evaluation Thesaurus, fourth ed. Sage Publications, Newbury Park, CA.
Scriven, M., 1996. Types of evaluation and types of evaluator. American Journal of Evaluation 17, 151–161.
Segan, D.B., Bottrill, M.C., Baxter, P.W.J., Possingham, H.P., 2011. Using conservation evidence to guide management. Conservation Biology 25, 200–202.
Smeets, E., Weterings, R., 1999. Environmental Indicators: Typology and Overview. Technical Report No 25. European Environment Agency, Copenhagen.
Stem, C., Margoluis, R., Salafsky, N., Brown, M., 2005. Monitoring and evaluation in conservation: a review of trends and approaches. Conservation Biology 19, 295–309.
Stephanson, S.L., Mascia, M.B., in press. Putting People on the Map: An Approach to Integrating Social Data in Conservation Planning. Conservation Biology.
Stevens, A., Milne, R., 1997. The Effectiveness Revolution and Public Health. Progress in Public Health. Royal Society of Medicine Press, London, pp. 197–225.
Stewart, G.B., Bayliss, H.R., Showler, D.A., Sutherland, W.J., Pullin, A.S., 2009a. Effectiveness of engineered in-stream structure mitigation measures to increase salmonid abundance: a systematic review. Ecological Applications 19, 931–941.
Stewart, G.B., Kaiser, M.J., Côté, I.M., Halpern, B.S., Lester, S.E., Bayliss, H.R., Pullin, A.S., 2009b. Temperate marine reserves: global ecological effects and guidelines for future networks. Conservation Letters 2, 243–253.
Stoll-Kleemann, S., 2010. Evaluation of management effectiveness in protected areas: methodologies and results. Basic and Applied Ecology 11, 377–382.
Stolton, S., Hockings, M., Dudley, N., MacKinnon, K., Whitten, T., Leverington, F., 2007. Management Effectiveness Tracking Tool: Reporting Progress at Protected Area Sites, second ed. WWF International, Gland, Switzerland.
Sutherland, W.J., Pullin, A.S., Dolman, P.M., Knight, T.M., 2004. The need for evidence-based conservation. Trends in Ecology & Evolution 19, 305–308.
Ticheler, H.J., Kolding, J., Chanda, B., 1998. Participation of local fishermen in scientific fisheries data collection: a case study from the Bangweulu Swamps, Zambia. Fisheries Management and Ecology 5, 81–92.
UNDP/GEF, 2005. Measuring and demonstrating impact, In: UNDP/GEF Resource Kit (No. 2). United Nations Environment Department/Global Environment Facility, Washington, DC.
USAID (U.S. Agency for International Development), 2011. USAID Evaluation Policy. U.S. Agency for International Development, Washington, DC.
Weiss, C.H., 1995. Nothing as practical as good theory: exploring theory-based evaluation for comprehensive community initiatives for children and families. In: Connell, J.I., Kubisch, A.C., Schorr, L.B., Weiss, C.H. (Eds.), New Approaches to Evaluating Community Initiatives: Concepts, Methods, and Contexts. Aspen Institute, Washington, DC, pp. 65–92.
Wholey, J., 1996. Formative and summative evaluation: related issues in performance measurement. American Journal of Evaluation 17, 145–149.
Wholey, J.S., 1997. Trends in performance measurement: challenges for evaluators. In: Chelimsky, E., Shadish, W.R. (Eds.), Evaluation for the 21st Century: A Handbook. SAGE Publications Inc., Thousand Oaks, California, pp. 124–133.
Yoccoz, N.G., Nichols, J.D., Boulinier, T., 2001. Monitoring of biological diversity in space and time. Trends in Ecology & Evolution 16, 446–453.
ZIMSTAT (Zimbabwe National Statistics Agency), ICF International, 2012. Zimbabwe Demographic and Health Survey 2010–11. ZIMSTAT and ICF International Inc., Calverton, Maryland.

APPENDIX VI

Danielsen, F., Burgess, N.D., Balmford, A., Donald, P.F., Funder, M., Jones, J.P.G., Alviola, P., Balete, D.S., Blomley, T., Brashares, J., Child, B., Enghoff, M., Fjeldså, J., Holt, S., Hübertz, H., Jensen, A.E., Jensen, P.M., Massao, J., Mendoza, M.M., Ngaga, Y., Poulsen, M.K., Rueda, R., Sam, M., Skielboe, T., Stuart-Hill, G., Topp-Jørgensen, E. and Yonten, D. 2009.
Local participation in natural resource monitoring: a characterization of approaches.
Conservation Biology 23: 31–42.

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Contributed Paper

Local Participation in Natural Resource Monitoring: a Characterization of Approaches

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Abstract: *The monitoring of trends in the status of species or habitats is routine in developed countries, where it is funded by the state or large nongovernmental organizations and often involves large numbers of skilled amateur volunteers. Far less monitoring of natural resources takes place in developing countries, where state agencies have small budgets, there are fewer skilled professionals or amateurs, and socioeconomic conditions prevent development of a culture of volunteerism. The resulting lack of knowledge about trends in species and habitats presents a serious challenge for detecting, understanding, and reversing declines in natural resource values. International environmental agreements require signatories undertake systematic monitoring of their natural resources, but no system exists to guide the development and expansion of monitoring schemes. To help develop such a protocol, we suggest a typology of monitoring categories, defined by their degree of local participation, ranging from no local involvement with monitoring undertaken by professional researchers to an entirely local effort with monitoring undertaken by local people. We assessed the strengths and weaknesses of each monitoring category and the potential of each to be sustainable in developed or developing countries. Locally based monitoring is particularly relevant in developing countries, where it can lead to rapid decisions*

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Paper submitted May 27, 2007; revised manuscript accepted May 27, 2008.

Conservation Biology, Volume 23, No. 1, 31–42
©2008 Society for Conservation Biology
DOI: 10.1111/j.1523-1739.2008.01063.x

to solve the key threats affecting natural resources, can empower local communities to better manage their resources, and can refine sustainable-use strategies to improve local livelihoods. Nevertheless, we recognize that the accuracy and precision of the monitoring undertaken by local communities in different situations needs further study and field protocols need to be further developed to get the best from the unrealized potential of this approach. A challenge to conservation biologists is to identify and establish the monitoring system most relevant to a particular situation and to develop methods to integrate outputs from across the spectrum of monitoring schemes to produce wider indices of natural resources that capture the strengths of each.

Keywords: biodiversity assessment, conservation, local stakeholders, monitoring schemes, natural resource management

Participación Local en el Monitoreo de Recursos Naturales: una Caracterización de Métodos

Resumen: *El monitoreo de tendencias en el estatus de especies o hábitats es rutinario en los países desarrollados, donde es financiado por el estado o por grandes organizaciones no gubernamentales y a menudo involucra a grandes números de voluntarios amateurs competentes. El monitoreo de recursos naturales es menos intenso en los países en desarrollo, donde las agencias estatales tienen presupuestos pequeños, hay menos profesionales o amateurs competentes y las condiciones socioeconómicas limitan el desarrollo de una cultura de voluntariado. La consecuente falta de conocimientos sobre las tendencias de las especies y los hábitats presenta un serio reto para la detección, entendimiento y reversión de las declinaciones de los recursos naturales. Los tratados ambientales internacionales requieren que los signatarios realicen monitoreos sistemáticos de sus recursos naturales, pero no existe un sistema para guiar el desarrollo y la expansión de los esquemas de monitoreo. Para ayudar al desarrollo de tal protocolo, sugerimos una tipología de categorías de monitoreo, definidas por el nivel de participación local, desde ningún involucramiento local con el monitoreo realizado por investigadores profesionales hasta un esfuerzo completamente local con el monitoreo llevado a cabo por habitantes locales. Evaluamos las fortalezas y debilidades de cada categoría de monitoreo, así como su sustentabilidad potencial en países desarrollados o en desarrollo. El monitoreo basado localmente es particularmente relevante en los países en desarrollo, donde puede llevar a decisiones rápidas para resolver amenazas clave sobre sus recursos naturales, puede facultar a las comunidades locales para un mejor manejo de sus recursos naturales y puede refinar las estrategias de uso sustentable para mejorar la forma de vida local. Sin embargo, reconocemos que la precisión y exactitud del monitoreo llevado a cabo por comunidades locales en situaciones diferentes requiere de mayor estudio y los protocolos de campo requieren de mayor desarrollo para obtener lo mejor del potencial de este método. Un reto para los biólogos de la conservación es la identificación y establecimiento del sistema de monitoreo más relevante para la situación particular, así como el desarrollo de métodos para integrar los resultados de una gama de esquemas de monitoreo para producir índices de recursos naturales más amplios que capturen las fortalezas de cada uno.*

Palabras Clave: conservación, evaluación de la biodiversidad, esquemas de monitoreo, intereses locales, manejo de recursos naturales

Introduction

Monitoring has been defined as "the systematic measurement of variables and processes over time" and "assumes that there is a specific reason for that collection of data, such as ensuring that standards are being met" (Spellerberg 2005). Monitoring of natural resources has become increasingly important, and various international agreements, such as the Millennium Development Goals and the national legislative frameworks of many countries, rely on an adequate knowledge of trends in species and habitats to make informed policy decisions. Despite legal frameworks and an obvious need, however, monitoring often receives low priority because it can be difficult and expensive to coordinate. Thus, monitoring of the impacts of conservation policy intervention falls well behind that of most other policy fields (Ferraro & Pattanayak 2006; Donald et al. 2007).

Most of the literature on methods of natural resource monitoring covers an externally driven approach in which professional researchers from outside the study area set up, run, and analyze the results from a monitoring programme that has been funded by a remote agency (e.g., Goldsmith 1991; Sutherland 1996; Thompson et al. 1998; Bibby et al. 2000; Spellerberg 2005). This approach has been criticized for being expensive to sustain over time and reliant on skills that are not endemic (Sheil 2001). Linking monitoring to the decisions of local people may help make monitoring more relevant locally and hence sustainable (Danielsen et al. 2005*a*). In developed countries this has been facilitated by citizen-scientist programs, in which professional scientists develop a

coordinated network of volunteers, many of whom may have no specific scientific training, who undertake research-related tasks such as observation, measurement, or computation (e.g., Greenwood 2007). Elsewhere, landowners who control a particularly valuable natural resource (habitat or species) often have a strong interest in monitoring these using their own resources so that they can make management decisions related to harvesting the resource (e.g., monitoring linked to shooting of Red Grouse [*Lagopus lagopus*] in the United Kingdom [www.gct.org.uk]).

These solutions to enhancing natural resource monitoring are uncommon in developing countries, where there are few volunteers and only a small group of professional experts (Sheil 2001; Danielsen et al. 2005*a*). Developing country realities suggest the need for other forms of monitoring—approaches that are simple, cheap, and require few resources (Danielsen et al. 2005*a*).

Discussion of the relative benefits and disadvantages of professional-researcher-executed and locally based monitoring tends to focus on these 2 extremes (Gilchrist et al. 2005), but in reality these simply form the ends of a spectrum of possible monitoring protocols. If monitoring the planet's natural resources is to be guided, or indeed itself monitored, it is necessary to examine this gradient more closely. To stimulate a more nuanced debate, we suggest a typology of monitoring schemes determined on the basis of relative contributions of local stakeholders (community members, volunteers, or locally employed staff such as rangers) and professional researchers. We reviewed the characteristics of these categories and provide examples from around the world. Finally, we suggest how this typology could be used to select an appropriate monitoring scheme for different circumstances and management needs, because making indicators fit for a purpose (e.g., maximizing improvements to decision making given limited resources) is a recognized challenge of monitoring (Mace & Baillie 2007).

Classification of Monitoring Schemes

We used the level of relative involvement of local stakeholders and professional scientists in monitoring to identify 5 categories of monitoring schemes (Table 1 and Supporting Information Fig. S.1) that between them span the full spectrum of monitoring protocols.

Category 1. Externally Driven, Professionally Executed Monitoring

These schemes do not involve local stakeholders. Design of the scheme, analysis of the results, and management decisions derived from these analyses are all undertaken by professional scientists funded by external agencies. Many existing monitoring schemes, particularly those organized by government agencies or global schemes funded by international organizations, fall into this category (e.g., forest-inventory plots, remote sensing of forest cover) (Table 1).

Category 2. Externally Driven Monitoring with Local Data Collectors

This category of monitoring scheme involves local stakeholders only in data collection. The design, analysis, and interpretation of the monitoring results are undertaken by professional researchers—generally far from the site. In developed countries, participants are often volunteers who donate their time freely (e.g., to monitor water and air quality, vegetation, weather, and the populations of birds, amphibians, fishes, invertebrates, and invasive species) (Table 1). Commercially exploited wildlife populations are also monitored by volunteers through, for example, fisheries statistics, hunter records, and angler–diary programs. These citizen science schemes often involve hundreds or thousands of volunteers (e.g., Gibbons et al. 2007) whose efforts are embedded within a strong organizational infrastructure that provides sophisticated professional support and feedback to the participating volunteers. In developing countries, there are fewer examples of volunteer monitoring. Nevertheless, local stakeholders in developing countries may be involved in this category of scheme by being paid to collect data as rangers working in protected areas, as staff on scientific expeditions, as staff assisting volunteer tourists to do monitoring work, or within hunter- or fisher-monitoring schemes (Table 1). We provide one detailed example of a category 2 scheme in Zambia.

Category 3. Collaborative Monitoring with External Data Interpretation

This category of monitoring scheme involves local people in data collection and management-oriented decision making, but the design of the scheme and the data analysis are undertaken by external scientists. Local people may either be paid for their time or contribute their time freely. Because analysis of category 3 data is not undertaken by local people, it may not incorporate local-stakeholder perspectives. This is significantly different from categories 4 and 5, in which local people are also involved in carrying out the analysis on which subsequent decision making is based. Category 3 monitoring schemes exist in the developed and developing world (Table 1). We provide a detailed example of a category-3 scheme in Madagascar.

Category 4. Collaborative Monitoring with Local Data Interpretation

Locally based monitoring schemes involve local stakeholders in data collection, interpretation or analysis, and management decision making, although external

Table 1. Role of local and professional researchers in the different categories of natural resource monitoring schemes.

Category of monitoring	*Primary data gathers*	*Primary users of data*	*Examples of monitoring schemes*[*]
1. Externally driven, professionally executed	professional researchers	professional researchers	forest inventory plots (Condit 1998; www.teaminitiative.org), remote sensing of forest cover (Mayaux et al. 2005), water-quality monitoring (www.gemswater.org/), water-flow assessments (Morishita et al. 2004), and World Database of Protected Areas (www.unep-wcmc.org/protected_areas/)
2. Externally driven with local data collectors	professional researchers, local people	professional researchers	volunteers monitoring of water/air quality (Savan et al. 2003), vegetation (Brandon et al. 2003), weather and climate change (www.on.ec.gc.ca/canwarn/), mammals (Toms & Newson 2006), birds (Gregory et al. 2005; Greenwood 2007), amphibians (http://armi.usgs.gov), fish (Schmitt & Sullivan 1996), invertebrates (www.bugwise.net.au/involved; Roy et al. 2007), and invasive species (Boudreau & Yan 2004); fisher, angler, and hunter records schemes (Ericsson & Wallin 1999; Bray & Schramm 2001; Pauly & Watson 2005); data collection by paid local people in the Arctic (e.g., observing caribou *Rangifer tarandus* from helicopter in Greenland; Cuyler et al. 2002); in developing countries data collection by paid local people on scientific expeditions or at field observatories (e.g., Sangalaki marine turtle breeding station, Indonesia; www.bestari.org); ranger-based monitoring in Ghana (Brashares & Sam 2005); volunteer tourist monitoring of coral reefs (Mumby et al. 1995; Darwall & Dulvy 1996); experimental fisher/hunter records schemes (Marks 1994; Ticheler et al. 1998)
3. Collaborative monitoring with external data interpretation	local people with professional researcher advice	local people and professional researchers	community-based monitoring of wetlands in Madagascar (Andrianandrasana et al. 2005) and BirdLife International's Important Bird Areas in Kenya (Bennun et al. 2005); bicycle transects of large mammals in Zimbabwe (Gaidet et al. 2003); hunter self-monitoring in the Bolivian Chaco (Noss et al. 2005); in developed countries, hunter-records schemes such as wildlife triangle monitoring in Russia and Finland (Lindén et al. 1996)
4. Collaborative monitoring with local data interpretation	local people with professional researcher advice	local people	ranger and community-based monitoring of resource use and wildlife in China (Rijsoort & Jinfeng 2005), Laos (Poulsen & Luanglath 2005), the Philippines (Danielsen et al. 2005b; Uychiaoco et al. 2005), East Africa (Obura et al. 2002; Topp-Jørgensen et al. 2005), Namibia (Stuart-Hill et al. 2005), and Ecuador (Becker et al. 2005; Townsend et al. 2005); in developed countries, monitoring by volunteer wardens at nature reserves and by amateur naturalists (the Neighbourhood Nestwatch scheme; Evans et al. 2005)
5. Autonomous local monitoring	local people	local people	customary conservation regimes in the Canadian Arctic (Ferguson et al. 1998; Moller et al. 2004), Indonesia (Mantjoro 1996), Laos (Baird 1999), Mexico (LaRochelle & Berkes 2003), Mongolia (Fernandez-Gimenez 2000), New Zealand (Moller et al. 2004), and the Pacific Islands (Johannes 1978, 1998); in developed countries, also fishing and hunter clubs monitoring of, for example, moose (*Alces alces*), bears (*Ursus* spp.), trout and salmon (*Salmo* spp.)

[*]*See Supporting Information for literature cited.*

scientists may provide advice and training. The original data collected by local people remain in the area being monitored, which helps create local ownership of the scheme and its results, but copies of the data may be sent to professional researchers for in-depth or larger-scale analysis. Examples of category 4 schemes in developed countries include volunteer wardens at nature reserves collecting data, using them as the basis for local management decisions, and providing them to national schemes for larger-scale analyses. Developing countries also have examples of this category of monitoring scheme, including community-based monitoring schemes operating in protected areas or community-managed areas (Table 1). Nevertheless, many of these are still at the pilot stage and still externally supported. We provide a detailed case example of a category 4 scheme from the Philippines.

Category 5. Autonomous Local Monitoring

In this category the whole monitoring process—from design, to data collection, to analysis, and finally to use of data for management decisions—is carried out autonomously by local stakeholders. There is no direct involvement of external agencies, except possibly to help advocate the continued relevance of such schemes. In developed countries category 5 schemes include natural resource monitoring among indigenous groups in New Zealand and the Canadian Arctic (Table 1) and on privately owned land managed by hunting and fishing clubs, where careful monitoring of high-value species takes place (e.g., trout and salmon [*Salmo* spp.] and bears [*Ursus* spp.]). In developing countries many customary systems of natural resource management rely on a locally evolved monitoring scheme to ensure that the valued attributes are maintained. Examples include Laotian freshwater fisheries, the Indonesian *sasi* system, and Pacific reef tenure (Table 1). Because many of these schemes are informal and exist within traditional societies that are located far from research institutions, there is little scientific documentation of the results (Berkes 1999).

The continuum of monitoring approaches mirrors the devolution of management responsibility in different approaches to natural resource management. The most locally based monitoring schemes (category 5) are typically part of "traditional" or "customary" systems of conservation management, and management responsibility might always have been at that level. The second-most locally based scheme (category 4) is equivalent to community-based natural resource management, in which management decisions and other rights have been devolved to the community. Monitoring schemes within category 3 and partly in category 2 mirror some of the more collaborative schemes in natural resource management, for example, systems such as joint forest management in which management rights and responsibilities have not been devolved but there is a sharing of management costs and benefits. Finally, the least locally based of the monitoring schemes (category 1 and partly category 2) parallel those conservation approaches that do not involve local people and in which the majority of decisions are made by remote government agencies or nongovernmental organization (NGOs).

Characteristics of Monitoring-Scheme Categories

We assessed the different categories of monitoring against the following criteria: costs to local stakeholders; costs to others; requirement for local expertise; requirement for external expertise; accuracy and precision; promptness of decision making; potential for enhancing local stakeholder capacity; and capacity to inform national and international monitoring schemes (Tables 2 & 3). To some extent, these criteria follow from how we categorized the monitoring schemes; hence, we focused only on the most pertinent points that separate monitoring schemes from each other.

Cost to Local Stakeholders

Costs to local people vary considerably across categories of monitoring schemes and generally increase with category number (Table 2). In category 1 schemes local people are not involved and hence do not incur costs. In category 2 schemes the costs to local volunteers can be considerable because people have to commit themselves to a program of regular visits, often at set times. For example, it has been estimated that in the United Kingdom, volunteers spend around 1.6 million h each year contributing to bird surveys, work that would cost at least $40 million to undertake professionally (http://www.bto.org/news/news2006/julaug/20_million_contribution.htm). Where local people participate in category 2 schemes in developing countries, they are usually paid for their time. Category 3 and 4 schemes have extensive involvement of local people who are not usually paid for their time, although materials and transport may be supplied. In category 5 schemes local people bear all the costs.

Cost to Others

Costs to nonlocal stakeholders also vary considerably across monitoring schemes. Category 1 schemes have high costs for salaries of professional researchers, with an example cost from Bwindi Impenetrable National Park in Uganda of \$3.6 ha^{-1} $year^{-1}$ (Danielsen et al. 2005*a*). Costs of a category-2 scheme in a developing country are \$0.06 ha^{-1} $year^{-1}$, category-3 schemes range from \$0.01 to \$0.13 ha^{-1} $year^{-1}$, and category-4 schemes have a median cost from 7 examples of \$0.05 ha^{-1} $year^{-1}$ (Danielsen et al. 2005*a*). There are no external costs for category 5 monitoring schemes.

Table 2. Variation in 8 characteristics across the 5 different categories of natural resource monitoring schemes.

	Characteristic[a]							
Monitoring category[b]	*cost to local stakeholders*	*cost to others (outsiders)*	*requirement for local expertise*	*requirement for external expertise*	*accuracy and precision*	*promptness of decision making*	*potential for enhancing local stakeholder capacity*	*capacity to inform national and international monitoring schemes*
Category 1	*	***	*	***	***[c]	*[d]	*	***
Category 2	**	**	**	***	***	*	*	***
Category 3	**	**	**	***	***	*	**	***
Category 4	***	*-***[e]	***	**-***[f]	**	***	***	**
Category 5	***	*	***	*	*	***	***	*

[a] *Key: *, low; **, intermediate; ***, high.*
[b] *Monitoring categories are defined in the text.*
[c] *Especially in developing countries, local people may be needed for locating and identifying (e.g., tracks of) wildlife species.*
[d] *An exception is remote-sensing schemes that detect, for example, forest fire in near real time and potentially may allow for almost immediate decision making.*
[e] *Recurrent costs to nonlocals low, set-up and training costs to nonlocals high.*
[f] *Recurrent requirement for nonlocal expertise intermediate; during set up/training requirement for nonlocal expertise high.*

Requirement for Local Expertise

Because the categories are defined by their degree of local participation, it follows that requirements for local participation vary across categories. There is no local involvement in category 1 schemes, but the need for local expertise is substantial in other categories (Table 2). The volunteers or locally employed people involved with category 2 schemes often need to have considerable species-identification expertise and must keep records and follow a prescribed method with procedural rigor. In category 3 schemes significant biological expertise is also required, but there is an additional need to make decisions on the basis of the results of monitoring. In category 4 and 5 schemes there is a need for a high level of local expertise in selecting relevant methods, interpreting data, and making management decisions. The need for local social and community-relations expertise is also significant in these categories.

Requirement for External Expertise

The requirement for external expertise is particularly high in the category 1 schemes and may slowly decline from category 2 to 4 schemes. By definition, there is no external involvement in category 5 schemes. Across the schemes, there may be a change in the balance of types of expertise between those focused on natural sciences and those that require participatory social-anthropological and facilitation skills, but socioeconomic literacy is required at every stage if the scheme is to be efficient and sustainable. In category 4 schemes the level of external engagement in day-to-day implementation declines dramatically, but significant external expertise may be required before the scheme can function independently.

Accuracy and Precision

For all categories of monitoring scheme, careful consideration of likely biases in the sampling strategy and survey methods, and thorough training of data gatherers and data interpreters will improve accuracy and the precision (Yoccoz et al. 2001, 2003; Nichols & Williams 2006; Holck 2007). Category 1 schemes often aim for a high level of accuracy and precision and may explicitly consider the power of the study to detect trends of interest (Hatch 2003; Maxwell & Jennings 2005). Category 2 schemes are vulnerable to bias due to the spatial or temporal coverage of monitoring, a lack of experienced observers, methods changing over time, and results reflecting observer perceptions (Bibby et al. 2000; Danielsen et al. 2005*a*), although methods exist to circumvent such biases (Greenwood 2007). There is hardly any literature on the degree of accuracy or precision of category 3 through 5 monitoring approaches (but see Uychiaoco et al. 2005). Overall, accuracy and precision probably decline from category 1 to 5 schemes (Table 2), but there is a need for scientific assessment of this assertion within carefully designed comparisons.

Promptness of Decision Making

The speed of decision making is predicted to rise progressively through category 1 to 5 schemes (Table 2). Different categories of monitoring schemes tend to lead to decisions made at different scales that address different categories of threats and result in different types of actions (Danielsen et al. 2005*a*). Only one empirical study has addressed the speed with which conservation-management decisions have been made as a consequence of locally based monitoring (Danielsen et al. 2005*b*). The rapid decision making possible in category 4 and 5

Table 3. Potential ways to avoid the pattern of variation in 8 characteristics across the 5 categories[a] of natural resource monitoring schemes, and proposed questions for those who will conduct monitoring to answer in the design phase.[b]

Characteristic							
cost to local stakeholders	*cost to others (outsiders)*	*requirement of local expertise*	*requirement of external expertise*	*accuracy and precision*	*promptness of decision making*	*potential for enhancing local stakeholder capacity*	*capacity to inform national and international monitoring schemes*
Careful design may reduce costs of categories 3 and 4.	Careful design may reduce costs of categories 1, 2, 3, and 4.	Need unavoidable?	Careful design may reduce need in categories 1, 2, and 3.	Careful design may reduce need in categories 1, 2, 3, and 4.	Promptness may require supportive environment to maximize benefits of categories 3, 4, and 5.	Enhancement may require supportive environment to maximize benefits of categories 4 and 5.	With appropriate design and support, category-4 schemes could still feed up.
Are there local stakeholders who might benefit from being involved with monitoring? Are there local stakeholders involved with management, or are they excluded from being involved in some way?	What external resources are available? Are they sustainable over time?	What is local capacity (or scope for training) like?	What is availability of external expertise?	What is need for accuracy and precision?	What is need for immediacy and speed of decision making?	What is need for local empowerment?	What is need for global data from this scheme?

[a] *Categories are defined in the text.*
[b] *The way to avoid variation is listed first under each characteristic and questions follow.*

schemes requires a supportive policy and legal environment (Table 3). If local stakeholders have little control over resources, it is unlikely their monitoring will lead to prompt decision making.

Potential for Enhancing Local Stakeholder Capacity

The potential for enhancing local capacity increases from category 1 through 5 with the increasing involvement of local stakeholders (Table 2). Category-1 schemes contribute little or nothing to local capacity building. Category 2 schemes may improve capacity of volunteers or park rangers and help change attitudes among local community members. Category 3 and 4 schemes can empower local stakeholders and improve collaboration with management authorities by improving use of indigenous knowledge, strengthening community-based resource management systems, and providing more-transparent, accountable, and inclusive decision making (e.g., Andrianandrasana et al. 2005). The potential of category 3 and 4 schemes to enhance local capacity is maximized when leadership of these schemes is established locally rather than transferred to national or international organizations. Category 5 schemes constitute a fully internalized, local management system, and hence in principle provide the greatest local control over monitoring and decision making in natural resource management. Nevertheless, category 5 schemes do not necessarily address existing inequalities within local communities (e.g., exclusion of the poorest or gender imbalances), and hence can exclude the community members who depend the most on exploitation of natural resources. Moreover, because such schemes are undertaken without the involvement of external stakeholders, they may not improve collaboration between communities and, for example, government authorities or private business.

Capacity to Inform National and International Monitoring Schemes

The ability of monitoring schemes to integrate with other schemes to generate wider indices of natural resources probably declines progressively from category 1 through 5 schemes (Table 2). Category 1, 2, and 3 schemes may, if well designed, fairly easily feed data into larger-scale schemes (e.g., category-1 international schemes include water-quality monitoring [www.gemswater.org/] and a database on the world's parks [www.unep-wcmc.org/protected_areas/] and their management effectiveness [Stolton et al. 2003]).

Many category 2 volunteer schemes are designed for large-scale use (e.g., the Marine Trophic Index [Pauly & Watson 2005] and Internet-based bird-recording schemes [Roberts et al. 2005]). National category 2 bird monitoring schemes across Europe have been combined to produce an international monitoring index of common birds, even though the various national schemes use different recording methods (Gregory et al. 2005). Among category 3 schemes, BirdLife International's Important Bird Area monitoring scheme provides data from the local level for both national and international analysis (Bennun et al. 2005).

Data from category 4 schemes are beginning to be aggregated for national-level analysis in Tanzania (Blomley et al. 2008), Namibia (Stuart-Hill et al. 2005), and the Philippines (Danielsen et al. 2005*b*). These initiatives, although promising, are still in their infancy. Some category 4 data are also used in global schemes (e.g., World Wide Fund for Nature's Living Planet Index [Loh et al. 2005]). We know of no category 5 schemes that are contributing data to larger-scale analyses. This is unsurprising because the schemes are fully self-determined, the variables monitored are often locally defined (e.g., presence of particular species, flow of rivers), and there is little communication with external agencies.

Category 2 through 4 schemes seem particularly well suited for collecting data on some important attributes that are difficult to monitor at a national or global level with professionally executed monitoring schemes. Examples include ecosystem goods and services delivered at the local scale and the condition of certain habitats, like fragmented forests and wetlands, whose loss proceeds primarily via degradation rather than wholesale conversion.

Examples of Locally Based Monitoring Schemes in Developing Countries

Monitoring that involves local stakeholders is already well established in many developed countries (e.g., volunteer bird-recording schemes). Nevertheless, we believe the locally based monitoring concept has great unexplored potential in developing countries, where funds and expertise are limited and people are more dependent on natural resources. Here we provide examples of category 2 through 4 monitoring schemes from developing countries.

Category 2 Scheme: Fisher Data Collection in the Bangweulu Swamps, Zambia

The Zambian government has collected fisheries statistics in Lake Bangweulu for many years. The methods of this category-1 monitoring scheme are similar to those proposed by the United Nations Development Programme/Food and Agriculture Organization Fisheries Division in the 1970s. The frequency and consistency has varied greatly, depending on availability of finance and workers; thus, the data are too few or unreliable to allow much meaningful analysis (Ticheler et al. 1998).

To solve this problem, 12 literate professional fishers living in the swamps were selected to carry out part of

the sampling in parallel with the monthly experimental gill-net surveys by scientists. Some used their own gear, whereas others were issued experimental gill nets, but the fish caught belonged to the fishers, and they were free to fish when and where they wanted as long as some basic information was recorded. The information collected was kept to a minimum and made as simple as possible. For each catch, only data on the time of fishing, fishing method, and locality were recorded. Each individual fish caught was recorded by species, mesh size in which it was caught, and the length to the nearest centimeter. Fishing effort that resulted in no catches was also recorded. Fishers were paid a fixed monthly wage for sampling and an additional sampling bonus for persistent and good-quality data, and data collected were passed to government officials during monthly supervisory visits.

The 12 fishers collected length-frequency data for 1 year. Large quantities of reliable and cheap length-frequency data were collected, and they allowed for a full length–based stock assessment, including cohort analysis. Fishers collected nearly 400,000 individual fish records. On the basis of costs per individual fish record, data collected by the fishers were nearly 60% cheaper than data collected by scientists in the experimental gill-net surveys. Data from local fishers and government scientists were complementary. Fishers collected large quantities of reliable length-frequency data, but they did not assess sex ratios, and hence there was added value from the detailed government monitoring with stationary gill nets. In a large inaccessible area such as the Bangweulu swamps, involvement of local fishers in data collection was the most cost-effective way to complete an intensive assessment of the fishery.

Category 3 Scheme: Participatory Ecological Monitoring of the Alaotra Wetlands in Madagascar

The Alaotra wetlands are the largest in Madagascar. They are shallow and highly productive and thus valuable for people and biodiversity, but are also vulnerable to degradation, particularly via sedimentation. Since 2001 Durrell Wildlife Conservation Trust, government, NGO technicians, and local communities collected data on key species (e.g., waterbirds and a locally endemic lemur), and on useful natural resources (Andrianandrasana et al. 2005). Monitoring teams at each site consisted of up to 17 people: 10 villagers and 7 technicians. Following a preparatory visit, participants were chosen at an initial meeting to which all community members were invited. Selection criteria included a good knowledge of the marshes, and literacy. Participants were paid around $2/day, which is less than an average earning from fishing. The monitoring teams facilitated group discussions with fishers and measured and identified fish caught by fishers. The monitoring teams also observed lemurs and waterbirds along fixed canoe transects and delimited burned marsh areas with geographic positioning systems. Durrell Wildlife technicians had university degrees, whereas other technicians had a secondary school education. Since 2002 the village participants, most of whom had primary school education, received training in data collection.

The monitoring has assisted wetland management by guiding amendments to and increasing respect for a regional fishing convention, raising awareness, catalyzing the transfer of marsh management to communities, and stimulating collaboration and good governance. Monitoring showed trends in natural resources management over time (e.g., changes in number of annual marsh fires) and provided valuable data on the fishery. Surveys also provided information on levels of hunting of water birds and lemurs and the area of lemur occupancy.

Overall, monitoring provided useful data for decision making and started the process of building local pride in the environment and the ability to analyze the monitoring data locally. Nevertheless, there was significant external input to the monitoring, including into data analysis and much of the interpretation.

Category 4 Scheme: Community-Based Monitoring of Philippine Protected Areas

Until the 1990s most protected areas in the Philippines existed only on paper. In 1992 a new protected area act, the NIPAS Act, allowed for community participation in management of protected areas. In 1996 the World Bank and Danish aid (DANIDA) agreed to assist the Philippine government to operationalize the new act, and for 3 years they worked together to develop a simple community- and ranger-based scheme for monitoring in protected areas.

The scheme was intended to identify trends in important biodiversity assets and to use these trends to guide management action in protected areas. It also was intended to enhance participation of protected-area communities in management of the protected area (Danielsen et al. 2000). Data were collected by government rangers and volunteer community members. By allowing rangers to participate in field assessments, the scheme encouraged them to get into the field and improved their capacity for management. In each park monitoring focused on a list of 10–15 taxa and 5–10 signs of resource use, selected by local community members together with protected-area staff. Data were collected every 3 months. Data interpretation was undertaken locally by the protected-area staff and community members, and a small report was presented every quarter to the Management Council of each protected area. The report included the data set, a list of important observations of changes in species and resource use, and a list of proposed management interventions with a description of the issue identified, the

location, and the proposed action to be taken by the protected-area council (Danielsen et al. 2005*b*).

Before this monitoring scheme was established, there was little collaboration between local people and park authorities, and park monitoring was restricted to assessments of the quantity of extracted timber (Danielsen et al. 2005*b*, 2007*b*). As a result of 2.5 years of operation of the scheme by 97 rangers and 350 community volunteers, 156 interventions were undertaken in terrestrial, marine, and freshwater ecosystems (Danielsen et al. 2005*b*). The majority of these interventions were meaningful and justified, 47% targeted the 3 most serious threats to biodiversity at the site, and 90% were implemented without external support. Many of the interventions were jointly undertaken by community members and the management authorities or consisted of local bylaws in support of park management. As a result of monitoring, schemes to regulate indigenous resource use were reestablished with government recognition in several parks. Monitoring led to more-diversified management responses on the part of the authorities, including a more socially acceptable and effective approach to enforcement. The scheme continues at most of the sites where it was established, even though DANIDA support ceased in 2001. The government has promoted the scheme as a standard management tool in protected areas and it has spread to new sites.

Criteria for Choosing a Monitoring Scheme

The context and the aims of the initiative will define which schemes are most appropriate (Table 3). Whatever category is chosen, adequate financial and human resources must be available over a suitable time frame if the monitoring is to be effective.

Category 1 schemes can be executed almost anywhere because they are largely externally driven. They are most suitable where highly technical monitoring across large scales demands high levels of professional expertise and where there is a guaranteed source of funding that will permit this form of technical monitoring to be sustained over time (Table 4).

Category 2 schemes can be used where there are skilled volunteers or funds to pay staff for collection of field data (Table 4). These types of schemes are ideal when large numbers of people are required to collect data across wide geographical areas and on a regular basis. This capitalizes on the strength of getting the most data possible, even if accuracy or precision of each individual data point may not be as high as that obtained by highly trained professionals.

Category 3 and 4 schemes depend on local people making significant investment in monitoring. External stakeholders should not try to get monitoring "on the

Table 4. Criteria of importance for making decisions on which category of natural resource monitoring is most suitable for a given circumstance.[a]

Monitoring category[b]	*Highly accurate data required from the monitoring scheme*	*Government/ NGOs have budgets for monitoring with their own staff*	*Professional scientists available*	*Volunteers easily available*	*Government extension/ ranger staff available at local levels*	*Area remote and difficult for outsiders to access easily*	*Natural resources an important part of local livelihoods*	*Current management regimes allow local peoples' involvement (e.g., in parks and reserves)*	*Policy and legal environment supportive of community involvement in resource management*	*Empowering local people to make decisions about natural resource conservation an important objective of management*
Category 1	***	***	***							
Category 2	***	***	***	***	*	**	*		**	
Category 3	**	***	***	**	**	***	***	**	**	**
Category 4	**	**	**	**	**	***	***	***	***	***
Category 5	*			**		***	***	***	***	***

[a] *Key: ***, very relevant; **, relevant; *, sometimes relevant; blank, not relevant.*
[b] *Monitoring categories are defined in the text.*

cheap" by expecting local people to bear costs. Unless there are real benefits felt locally, such monitoring will not be sustainable (Hockley et al. 2005). They are therefore most appropriate where local people have significant interests in natural resource use (Table 4). In these schemes local ownership, empowerment, and link to management decisions can be even more important than data quality, although management and empowerment benefits should not be used as an excuse for poor design. A balance is therefore needed between monitoring goals and the broader goals of seeing the results used and decisions taken about natural resource management.

Category 5 schemes by definition cannot be instigated from outside. These types of monitoring schemes can be highly effective when a valuable resource is being monitored by people with a large stake in knowing the status of that resource (Table 4). In other category 5 schemes, the design and implementation may result in data that scientists would consider inaccurate and imprecise.

Need for Further Work

In some circumstances locally based monitoring has advantages over conventional monitoring (Danielsen et al. 2007*a*). It can build local capacity and relations between local people and the authorities, and can result in more-rapid management interventions. Nevertheless, the approach needs further development and verification. Systematic comparisons between professional and locally based monitoring approaches are needed, and there is a need to extend the focus of locally based monitoring from primarily biological monitoring to consider social measures (e.g., governance in natural resource management). Meta-analytical tools (Gurevitch et al. 2001) may offer opportunities for combining the results of locally based monitoring to draw general conclusions and to track larger-scale trends. For amalgamating results with meta-analysis, the main requirements are the use of a small number of methods, each well replicated, across a large number of schemes (Côte et al. 2005).

Finally, there is a need for larger-scale testing of locally based monitoring approaches tied to some of the local approaches to conservation management that are being promoted globally. Locally based monitoring may be the ideal way for communities to report to external agencies on progress with managing habitats, species, and flows of ecosystem services in community or comanaged conservation areas.

The world needs monitoring that makes a real contribution to improving natural resource management. It is therefore vital to improve the connection between the way conservation science is conducted and how it is applied.

Acknowledgments

We thank C. Kremen and G. Meffe for encouragement, H. Andrianandrasana, J. Durbin, M. Gray, A. Jørgensen, K. Laidre, K. Pirhofer, and S. Wangchuk for valuable discussions, and 5 anonymous reviewers for comments. This work was supported in part by the Danish Council for Development Research (104.DAN.8.1203), Nordic Agency for Development and Ecology (NORDECO), and World Wildlife Fund-US.

Supporting Information

A key to identify the category of a natural resource monitoring scheme and references cited in Table 1 are available as part of the on-line article. The author is responsible for the content and functionality of this material. Queries (other than absence of the material) should be directed to the corresponding author.

Literature Cited

Andrianandrasana, H. T., J. Randriamahefasoa, J. Durbin, R. E. Lewis, and J. H. Ratsimbazafy. 2005. Participatory ecological monitoring of the Alaotra wetland in Madagascar. Biodiversity and Conservation **14:**2757–2774.

Bennun, L., P. Matiku, R. Mulwa, S. Mwangi, and P. Buckley. 2005. Monitoring important bird areas in Africa: towards a sustainable and scaleable system. Biodiversity and Conservation **14:**2575–2590.

Berkes, F. 1999. Sacred ecology. Traditional ecological knowledge and resource management. Taylor & Francis, Philadelphia, Pennsylvania.

Bibby, C. J., N. D. Burgess, D. A. Hill, and S. Mustoe. 2000. Bird census techniques. 2nd edition. Academic Press, London.

Blomley, T., K. Pfliegner, J. Isango, E. Zahabu, A. Ahrends, and N. Burgess. 2008. Seeing the wood for the trees: an assessment of the impact of participatory forest management on forest condition in Tanzania. Oryx **42:**380–391.

Côté, I. M., J. A. Gill, T. A. Gardner, and A. R. Watkinson. 2005. Measuring coral reef decline through meta-analysis. Philosophical Transactions of the Royal Society of London B **360:**385–395.

Danielsen, F., D. S. Balete, M. K. Poulsen, M. Enghoff, C. M. Nozawa, and A. E. Jensen. 2000. A simple system for monitoring biodiversity in protected areas of a developing country. Biodiversity and Conservation **9:**1671–1705.

Danielsen, F., N. D. Burgess, and A. Balmford. 2005*a*. Monitoring matters: examining the potential of locally-based approaches. Biodiversity and Conservation **14:**2507–2542 (also available at www.monitoringmatters.org).

Danielsen, F., A. E. Jensen, P. A. Alviola, D. S. Balete, M. M. Mendoza, A. Tagtag, C. Custodio, and M. Enghoff. 2005*b*. Does monitoring matter? A quantitative assessment of management decisions from locally-based monitoring of protected areas. Biodiversity and Conservation **14:**2633–2652.

Danielsen, F., N. Burgess, and E. Topp-Jørgensen. 2007*a*. Native knowledge. Science (E-letter): www.sciencemag.org/cgi/eletters/315/5818/1518.

Danielsen, F., M. M. Mendoza, A. Tagtag, P. A. Alviola, D. S. Balete, A. E. Jensen, M. Enghoff, and M. K. Poulsen. 2007*b*. Increasing conservation management action by involving local people in natural resource monitoring. Ambio **36:**566–570.

Donald, P. F., F. J. Sanderson, I. J. Burfield, S. M. Bierman, R. D. Gregory, and Z. Waliczky. 2007. International conservation policy delivers benefits for birds in Europe. Science **317:**810–813.

Ferraro, P. J., and S. K. Pattanayak. 2006. Money for nothing? A call for empirical evaluation of biodiversity conservation investments. Public Library of Science Biology DOI:10.1371/journal.pbio.0040105.

Gibbons, D. W., P. F. Donald, H.-G. Bauer, L. Fornasari, and I. K. Dawson. 2007. Mapping avian distributions: the evolution of bird atlases. Bird Study **54:**324–334.

Gilchrist, G., M. Mallory, and F. Merkel. 2005. Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. Ecology and Society **10:**20.

Goldsmith, B., editor. 1991. Monitoring for conservation and ecology. Chapman & Hall, London.

Greenwood, J. J. D. 2007. Citizens, science and bird conservation. Journal of Ornithology **148:**S77–S124.

Gregory, R. D., A. van Strien, P. Vorisek, A. W. G. Meyling, D. G. Noble, R. P. B. Foppen, and D. W. Gibbons. 2005. Developing indicators for European birds. Philosophical Transactions of the Royal Society Biological Sciences **360:**269–288.

Gurevitch, J., P. S. Curtis, and M. H. Jones. 2001. Meta-analysis in ecology. Advances in Ecological Research **32:**199–247.

Hatch, S. A. 2003. Statistical power for detecting trends with applications to seabird monitoring. Biological Conservation **111:**317–329.

Hockley, N. J., J. P. G. Jones, F. B. Andriahajaina, A. Manica, F. E. Rakoto, E. H. Ranambitsoa, and J. A. Randriamboahary. 2005. When should communities and conservationists monitor exploited resources? Biodiversity and Conservation **14:**2795–2806.

Holck, M. 2007. Participatory forest monitoring: an assessment of the accuracy of simple cost-effective methods. Biodiversity and Conservation DOI:10.1007/s10531-007-9273-4.

Loh, J., R. E. Green, T. Ricketts, J. Lamoreux, M. Jenkins, V. Kapos, and J. Randers. 2005. The living planet index: using species population time series to track trends in biodiversity. Philosophical Transactions of the Royal Society of London B **360:**289–295.

Mace, G. M., and J. E. M. Baillie. 2007. The 2010 biodiversity indicators: challenges for science and policy. Conservation Biology **21:**1406–1413.

Maxwell, D., and S. Jennings. 2005. Power of monitoring programmes to detect decline and recovery of rare and vulnerable fish. Journal of Applied Ecology **42:**25–37.

Nichols, J. D., and B. K. Williams. 2006. Monitoring for conservation. Trends in Ecology & Evolution **21:**668–673.

Pauly, D., and R. Watson. 2005. Background and interpretation of the 'marine trophic index' as a measure of biodiversity. Philosophical Transactions of the Royal Society of London B **360:**415–424.

Rijsoort, J. V., and Z. Jinfeng. 2005. Participatory resource monitoring as a means for promoting social change in Yunnan, China. Biodiversity and Conservation **14:**2543–2573.

Roberts, R. L., P. F. Donald, and I. J. Fischer. 2005. Project wordbirds: developing a web-based data collection system for the global monitoring of bird distribution and abundance. Biodiversity and Conservation **14:**2807–2820.

Sheil, D. 2001. Conservation and biodiversity monitoring in the tropics: realities, priorities, and distractions. Conservation Biology **15:**1179–1182.

Spellerberg, I. F. 2005. Monitoring ecological change. Cambridge University Press, Cambridge, United Kingdom.

Stolton, S., M. Hockings, N. Dudley, K. MacKinnon, and T. Whitten. 2003. Reporting progress in protected areas: a site-level management effectiveness tracking tool. World Wide Fund for Nature and World Bank, Washington, D.C.

Stuart-Hill, G., R. Diggle, B. Munali, J. Tagg, and D. Ward. 2005. The Event Book System: a community based natural resource monitoring system from Namibia. Biodiversity and Conservation **14:**2611–2631.

Sutherland, W. J., editor. 1996. Ecological census techniques. Cambridge University Press, Cambridge, United Kingdom.

Thompson, W. L., G. C. White, and C. Gowan. 1998. Monitoring vertebrate populations. Academic Press, San Diego, California.

Ticheler, H. J., J. Kolding, and B. Chanda. 1998. Participation of local fishermen in scientific fisheries data collection: a case study from the Bangweulu Swamps, Zambia. Fisheries Management and Ecology **5:**81–92.

Uychiaoco, A. J., H. O. Arceo, S. J. Green, M. T. De la Cruz, P. A. Gaite, and P. M. Aliño. 2005. Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. Biodiversity and Conservation **14:**2775–2794.

Yoccoz, N. G., J. D. Nichols, and T. Boulinier. 2001. Monitoring of biological diversity in space and time. Trends in Ecology & Evolution **16:**446–453.

Yoccoz, N. G., J. D. Nichols, and T. Boulinier. 2003. Monitoring of biological diversity—a response to Danielsen et al. Oryx **37:**410.

APPENDIX VII

Danielsen, F., Pirhofer-Walzl, K., Adrian, T., Kapijimpanga, D., Burgess, N.D., Jensen, P.M., Bonney, R., Funder, M., Landa, A., Levermann, N. and Madsen, J. 2014.
Linking public participation in scientific research to the indicators and needs of international environmental agreements.
Conservation Letters 7: 12–24.

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LETTER

Linking Public Participation in Scientific Research to the Indicators and Needs of International Environmental Agreements

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Keywords
Adaptive management; Intergovernmental Platform on Biodiversity and Ecosystem Services; locally based monitoring; observing system; participatory monitoring; typology; 2020 target.

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Received
28 October 2012
Accepted
5 March 2013

Editor
H. Possingham

doi: 10.1111/conl.12024

Abstract

Different monitoring approaches collect data that can measure progress toward achieving global environmental indicators. These indicators can: (1) Audit management actions; (2) Inform policy choices; and (3) Raise awareness among the public and policy makers. We present a generic, empirically based, framework of different environmental monitoring approaches, ranging from scientist-driven to those undertaken by local people. This framework is used to assess monitoring possibilities for the Convention on Biological Diversity "2020" indicators, and those of 11 other international environmental agreements. Of the 186 indicators in these 12 environmental agreements, 69 (37%) require monitoring by professional scientists, whereas 117 (63%) can involve community members as "citizen scientists." Promoting "community-based" and "citizen science" approaches could significantly enrich monitoring progress within global environmental conventions. It would also link environmental monitoring to awareness raising and enhanced decision-making at all levels of resource management.

Introduction

There is broad international agreement that a better understanding is required of global status and trends in species, habitats, and ecosystem services (Butchart *et al.* 2010; Intergovernmental Platform on Biodiversity and Ecosystem Services 2013). Similarly, decision makers—from international to local—require a better understanding of progress in environmental initiatives and agreements (Mace & Baillie 2007). Moreover, because knowledge alone is insufficient to affect environmental change (Walker *et al.* 2009), changes in human attitudes and behavior are required to facilitate the achievement of environmental goals (Ehrlich & Kennedy 2005).

In response to the global environmental crisis, several hundred international environmental agreements have been adopted by countries around the world (Mitchell 2003). These induce countries to change policies, and some have delivered major improvements by reducing environmental problems such as acid rain in Europe,

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the frequency of oil spills, the release of ozone depleting gases, and international trade in threatened wildlife (Kanie 2007). One key environmental agreement is the Convention on Biological Diversity (CBD), which is intended to encourage governments to reverse declines in species and habitats and maintain the benefits to people from wild nature (Convention on Biological Diversity 2013). Failure of countries to achieve the CBD 2010 targets led the 10th Conference of the Parties to the CBD (October 2010) to adopt a revised plan for tackling biodiversity loss, which included 20 stronger, more comprehensive, more explicit, and more measurable targets for 2020 (Aichi biodiversity targets; United Nations Environment Programme [UNEP] & CBD 2010).

The new targets require indicators that can be monitored to track progress, and the process to develop these indicators has been initiated (UNEP, CBD 2010; Pereira *et al.* 2013). Structured frameworks of indicators assist the interpretation and presentation of results (Walpole *et al.* 2009), with the most widely used indicator framework being the "pressure, state, and response" framework of the Organization for Economic Cooperation and Development (OECD 1998). A slightly modified version has been proposed to organize indicators and reporting on the achievement of the 2020 targets to the CBD (Sparks *et al.* 2011).

Most indicators are developed assuming that data will be collected, interpreted, and analyzed by professional scientists. Involving local people in the collection and even interpretation of environmental data could, however, have many positive benefits, as demonstrated by the schemes known as "citizen science" (Shirk *et al.* 2012) or "community-based monitoring" (Fry 2011). Local stakeholder involvement would not only leverage effort in data collection (Possingham *et al.* 2012) but also enhance public engagement in addressing shared global concerns. The process of engaging many actors in the collection of monitoring data to measure different indicators could transform international agreements to instruments *of* change and processes *for* change (Walker *et al.* 2009).

Our past work used expert opinion to suggest that environmental monitoring approaches range from scientist-executed—with no involvement of local stakeholders—to autonomous local schemes with no involvement of scientists (Danielsen *et al.* 2009). Here, we evaluate whether different types of monitoring approaches, undertaken by a variety of stakeholder groups, can assist in measuring environmental indicators within major international conventions. We develop a framework of approaches to environmental monitoring, using multivariate statistical analysis to segment published monitoring schemes. To test the utility of this framework, we use it to assess data gathering possibilities for all indicators of 12 major international environmental agreements. Finally, we discuss how monitoring approaches that include local people might augment scientist-dominated methods, while also raising environmental awareness among the general public and policy makers.

Methods

Grouping monitoring approaches

We develop a statistically defined typology of environmental monitoring schemes based on 3,454 papers that present monitoring results, published between 1987 and 2012. From these, we identified 126 different schemes that focused on monitoring either species or populations, habitats or ecosystems, or resource use (Appendix S1). For each scheme, we coded 25 clearly distinct parameters that contributed to characterizing the type of scheme and which could be extracted from publications (Table 1). Each scheme was independently coded by two team members; in the few cases where their evaluations disagreed, they reached a conclusion on scoring through discussion. After coding, parameters or schemes with missing data and parameters not logically representing a span of numerical values were excluded from the cluster analysis. Seventeen of the parameters and 107 of the schemes had complete data (Appendixes S2 and S3). We then grouped these schemes using cluster analysis in the Programme R (Appendix S4).

Applying classification of monitoring schemes to international environmental agreements

To examine the utility of the classification of monitoring schemes identified using cluster analysis, we mapped different types onto indicators of 12 major international environmental agreements (see Table 2). The indicators were placed within the seven thematic areas (shown in Table 3) of the CBD work program before 2010, based on the topic of the indicators.

Assignment of monitoring scheme types to indicators was undertaken independently by F.D. and N.D.B. Where we disagreed, consensus was reached through discussion (data in Appendix S5). For each indicator, we assessed if it could be measured: (1) By professional scientists without involving local stakeholders; (2) By professional scientists with involvement of local stakeholders as data collectors; (3) By local stakeholders who collect, process, and interpret the data and present findings to indicator initiators or decision makers based on an original initiative to set up monitoring that was undertaken by outsiders; or (4) By

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Table 1 Parameters assessed for each published environmental monitoring scheme in order to develop the statistically defined framework of environmental monitoring approaches

	Topic of parameter	Options
	Before the monitoring	
a1	Initiative to monitor taken by	Who took the initiative[a]
a2	Objective of the monitoring: money or livelihood value?	Was the monitoring intended to increase the provision of food, water or income? 1) Yes 2) No
a3	Objective of the monitoring: ethical or esthetic value?	Was the monitoring intended to increase ethical or esthetic values? 1) Yes 2) No
a4	Climate of the area of the monitoring scheme (if the scheme covered >1 climatic zone, we listed the dominant climatic zone, in terms of area)	1) Polar 2) Temperate 3) Tropical
a5	Biome of the area of the monitoring scheme (if the scheme covered >1 biome, we listed the dominant biome, in terms of area)	1) Marine 2) Limnic 3) Terrestrial
a6	Continent of the area of the monitoring scheme	1) North America 2) Central/South America 3) Europe 4) Africa 5) Asia 6) Pacific 7) Australia 8) Antarctica
a7	Gross national income (GNI) per capita of the country of the monitoring scheme at the time of the assessment[b]	1) GNI per capita USD 2,570 or more[c] 2) GNI per capita <USD 2,570
a8	Land-tenure system of the area of the monitoring scheme (if the scheme was undertaken in an area with >1 land-tenure system, we listed the dominant land-tenure system, in terms of area or time)	1) Protected area under government authority 2) Protected area managed (partially or fully) by the local communities 3) Outside of protected areas
a9	Number of community members involved, or believed to be involved, in the monitoring scheme	1) >100 2) 50–100 3) 10–49 4) 1–9 5) 0
a10	Total size of area monitored by the monitoring scheme	1) 100,000 ha or more 2) 50,000–99,999 ha 3) 10,000–49,999 ha 4) 5,000–9,999 ha 5) 1–4,999 ha
a11	How much equipment was used to collect the data in the monitoring scheme?	1) People with >1 piece of mechanical scientific equipment 2) People with 1 piece of mechanical scientific equipment (e.g., binoculars, professional hand net, measure string) 3) People with no scientific equipment
a12	Attributes monitored by the monitoring scheme	1) >1 taxonomic group/resource 2) One taxonomic group/resource (e.g., fish)
a13	Spatial sampling scale of the monitoring scheme	1) International or largely international 2) Country or largely country 3) Village/catchment/protected-area, or largely village/catchment/protected-area
	During the monitoring	
b1	The monitoring scheme was funded by (recurrent costs; not including training)	Who paid for the monitoring[a]
b2	The monitoring scheme was designed by	Who designed the monitoring[a]
b3	The data collection in the monitoring scheme was undertaken by	Who collected the data[a]
b4	The data processing in the monitoring scheme was undertaken by	Who prepared the data for analysis[a]
b5	The data interpretation in the monitoring scheme was undertaken by	Who interpreted the results[a]
b6	The presentation of the findings from the monitoring scheme was presented to decision makers by	Who presented the findings to decision makers[a]

Continued

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Table 1 Continued

	Topic of parameter	Options
	After the monitoring	
c1	Decision-making	Who took (or were expected to take) decisions on the basis of the findings from the monitoring scheme[a]
c2	Implementation of decisions	Who carried out (or were expected to carry out) the management interventions emanating from the monitoring scheme[a]
c3	Scale of management impact	On which spatial scale did the management interventions impact[a]
c4	Policing	Who checked (or were expected to check) that the management interventions were being undertaken[a]
	Other information	
d1	Number of years of monitoring at the time of the assessment	1) >10 2) 5–10 1) <5
d2	Start year of the monitoring scheme (year)[d]	1) <1940 2) 1940–49 3) 1950–59 4) 1960–69 5) 1970–79 6) 1980–89 7) 1990–99 8) 2000–2009

[a]One of the following four options was used: (1) entirely external (national or international level); (2) more than 50% external (national or international level); (3) more than 50% internal (village or district level); and (4) entirely internal (village or district level).
[b]Source: World Bank (2012).
[c]Monitoring schemes in Antarctica were included in this category.
[d]For monitoring schemes that started a century or more ago, we used "<1940."

local stakeholders who set up the monitoring schemes and undertake the whole monitoring process, from design, to data collection, to analysis, and finally to use of data for management decisions on their own without any involvement of professional scientists. The criteria are not mutually exclusive and some indicators received multiple scores. To assess our own scoring, we also asked 13 experts from around the world (Appendix S1) to independently assign the monitoring scheme types to a random sample of 12.5% of the 186 indicators (Appendix S6). For every indicator, we also assessed the main constraints, if any, to the involvement of local stakeholders (Appendix S5). Finally, we determined for each indicator whether we knew of specific examples of monitoring schemes in which the indicator had been populated with data, as a measure of our certainty in the coding assigned.

For the assessment of the indicators of international environmental agreements, we defined monitoring as "the process of gathering information about state variables at different points in time for the purpose of drawing inferences about changes in state" (Yoccoz *et al.* 2001). Indicators, then, are "a metric that represents that state" (Jones *et al.* 2011). We defined local stakeholders as "local resource users, local government staff or amateur naturalists." We defined citizen science as "scientific research that use volunteers in data collection," and community-based monitoring as "monitoring of natural resources undertaken by local stakeholders using their own resources and in relation to aims and objectives that make sense to them."

Results

Our cluster analysis of 17 parameters among 107 monitoring schemes with complete data identifies a framework of monitoring approaches with five major types of monitoring schemes (Figure 1; Appendix S4). The most distinct monitoring schemes are within monitoring scheme type A (Figure 1) and have two unique characteristics: (1) Local stakeholders took the initiative to set them up and (2) They are fully financed locally: scientists are not involved. These schemes include, for example, monitoring in "customary" (Cinner & Aswani 2007) management regimes in the Pacific (Johannes 1998). The second most distinct group is monitoring scheme type B (Figure 1). In these schemes, the original initiative was taken by scientists but local stakeholders collect, process, and interpret the data. An example is the fishermen's and hunters' monitoring of coastal resources in Greenland (Danielsen *et al.* in press). The third most distinct group is monitoring scheme type C (Figure 1). These schemes were designed by scientists who also analyze the data, but

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Table 2 Proportion of indicators across 12 international environmental agreements that are suitable for monitoring using monitoring schemes of type A, B, C-D, and E of our framework. The table also shows the proportion of indicators that, for different reasons, are constrained in involving local stakeholders in their measurements, and, in addition, our confidence in the coding

		[b]Suitable monitoring approach				Constraints to local stakeholder involvement					
International agreement[a]	Indicators (*n*)	E, Scientist-executed monitoring[c] (%)	C-D, Collaborative monitoring with external data interpretation/externally driven monitoring with local data collectors[d] (%)	B, Collaborative monitoring with local data interpretation[e] (%)	A, Autonomous local monitoring[f] (%)	Area-based data required[g] (%)	National overview required[h] (%)	Legislative knowledge required[i] (%)	Data required from museums and herbaria (%)	Technically difficult[j] (%)	Certainty[k] (%)
AEWA	13	100	69	46	15	8	62	85	0	38	100
CBD	20	95	75	60	30	30	45	50	25	85	100
CBMP[l]	19	100	79	68	37	32	32	16	0	79	95
CITES	20	100	35	10	0	0	95	80	0	35	93
CMS	2	100	0	0	0	0	0	0	0	100	100
IOSEA	17	94	94	82	41	6	12	18	6	47	97
OECD	15	100	67	40	27	13	27	33	0	87	100
Ramsar	10	100	60	50	10	10	50	30	0	70	100
SEBI	26	100	81	62	35	15	27	35	12	69	83
UNCCD	28	100	29	21	14	25	64	68	0	25	98
UNFCCC	9	100	56	11	11	11	0	0	11	100	39
WHC	7	100	71	14	14	0	86	43	0	29	79
Total	186	99	63	44	23	16	45	44	5	59	92

[a]AEWA, Agreement on the Conservation of African-Eurasian Migratory Waterbirds; CBD, Convention on Biological Diversity; CBMP, Circumpolar Biodiversity Monitoring Program; CITES, Convention on International Trade in Endangered Species; CMS, Convention on Migratory Species; IOSEA, Indian Ocean—South-East Asian Marine Turtle Memorandum of Understanding; OECD, Organization for Economic Cooperation and Development; Ramsar, Convention on Wetlands of International Importance; SEBI, Streamlining European 2010 Biodiversity Indicators; UNCCD, United Nations Convention to Combat Desertification; UNFCCC, United Nations Framework Convention on Climate Change; and WHC, World Heritage Convention.

[b]The nomenclature for the subgroups of environmental monitoring schemes is modified from Danielsen *et al.* (2009).

[c]By professional scientists without involving local stakeholders.

[d]By professional scientists with involvement of local stakeholders as data collectors.

[e]By local stakeholders who collect, process, and interpret the data and present findings to indicator initiators or decision makers.

[f]By local stakeholders on their own without involving professional scientists.

[g]Requires area-based or remote sensing-based data.

[h]Requires a national or supranational overview.

[i]Requires knowledge of administrative, legislative, policy, regulatory, or managerial aspects.

[j]Difficult to monitor technically or analytically.

[k]The proportion of indicators (averaged between the two evaluators) where we personally knew of specific, or closely related, examples of monitoring schemes in which the indicators had been populated with data. This was used as a measure of our confidence in the coding we had provided.

[l]For this study, we consider CBMP an international agreement.

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Table 3 Proportion of indicators among 12 international environmental agreements across seven thematic areas that are suitable for monitoring schemes of type A, B, C-D, and E. The table also shows, for each thematic area, the proportion of indicators which, for different reasons, are constrained in involving local stakeholders in their measurements, and our confidence in the coding

		Suitable monitoring approach[a]				Constraints to local stakeholder involvement					
Thematic area	Indicators (*n*)	E, Scientist-executed monitoring[b] (%)	C-D, Collaborative monitoring with external data interpretation/externally driven monitoring with local data collectors[c] (%)	B, Collaborative monitoring with local data interpretation[d] (%)	A, Autonomous local monitoring[e] (%)	Area-based data required[f] (%)	National overview required[g] (%)	Legislative knowledge required[h] (%)	Data required from museums and herbaria (%)	Technically difficult[i] (%)	Certainty[j] (%)
Status of and trends in the components of biodiversity	28	100	68	46	21	32	54	32	14	93	100
Sustainable use	17	100	71	59	41	29	41	47	0	76	97
Threats to biodiversity	8	100	63	63	50	13	0	38	38	88	88
Ecosystem integrity and ecosystem goods and services	17	100	94	76	35	29	18	0	0	88	94
Status of traditional knowledge, innovations, and practices	3	67	100	100	33	0	0	33	0	33	83
Status of access and benefit-sharing	2	100	50	50	0	0	50	100	50	50	50
Status of resource transfers	10	100	50	30	10	0	70	60	0	0	95
Other thematic area	101	99	56	34	17	9	50	52	2	47	90
Total	186	99	63	44	23	16	45	44	5	59	92

[a]The nomenclature for the subgroups of environmental monitoring schemes is modified from Danielsen *et al.* (2009).
[b]By professional scientists without involving local stakeholders.
[c]By professional scientists with involvement of local stakeholders as data collectors.
[d]By local stakeholders who collect, process, and interpret the data and present findings to indicator initiators or decision makers.
[e]By local stakeholders on their own without involving professional scientists.
[f]Requires area-based or remote sensing-based data.
[g]Requires a national or supranational overview.
[h]Requires knowledge of administrative, legislative, policy, regulatory, or managerial aspects.
[i]Otherwise difficult to monitor technically or analytically.
[j]The proportion of indicators (averaged between the two evaluators) where we personally knew of specific, or closely related, examples of monitoring schemes in which the indicators had been populated with data.

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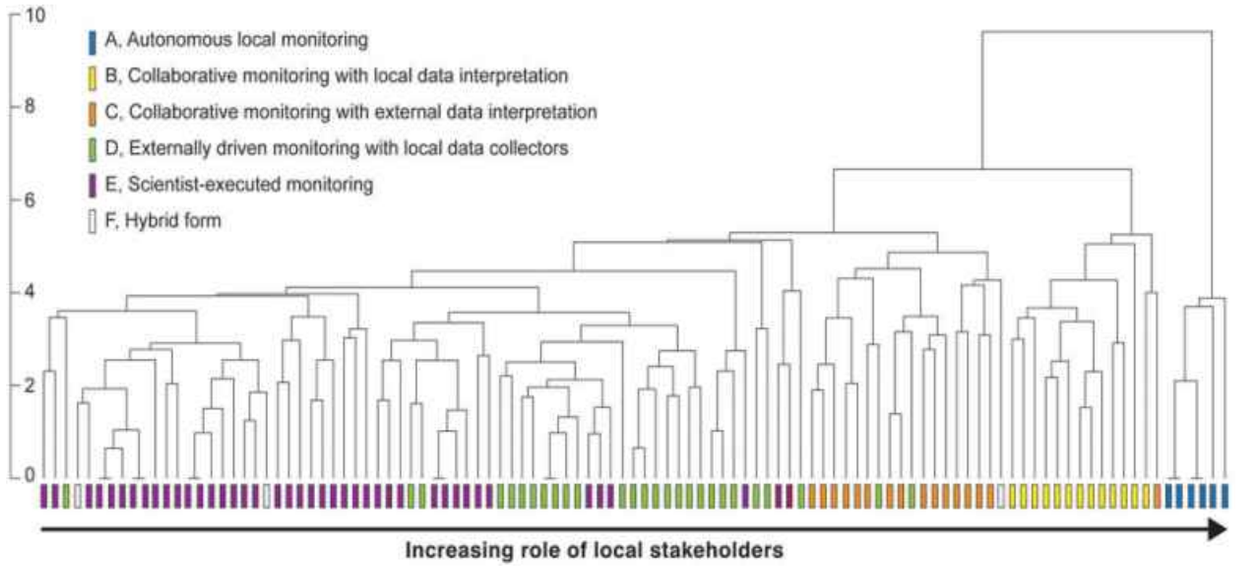

Figure 1 Dendrogram of environmental monitoring schemes, based on a cluster analysis of 17 parameters among 107 schemes published between 1987 and 2012. The relative role of local stakeholders in the monitoring schemes increases from left to right between the five types of monitoring schemes. The nomenclature for the types of environmental monitoring schemes is modified from Danielsen *et al.* 2009.

the local stakeholders collect the data, take decisions on the basis of the findings, and carry out the management interventions emanating from the monitoring scheme. These schemes include, for example, monitoring of shallow tropical marine fisheries in Kenya (Obura 2001). The least distinct clusters are monitoring scheme type D and E (Figure 1). In type D, local stakeholders are involved in data collection, but other activities are carried out by professional scientists. Examples of schemes of monitoring scheme type D include volunteers' monitoring of coral reefs in the Gulf of Mexico (Pattengill-Semmens & Semmens 1998) and other "citizen science" schemes (Shirk *et al.* 2012). In monitoring schemes of type E, all aspects of the monitoring are undertaken by professional scientists, without involvement of local stakeholders. The five types of monitoring scheme outlined are not mutually exclusive, and hybrid models exist (Figure 1; Appendix S2). The most important parameters in the clustering were who took the original initiative to set up the monitoring schemes, who funded them, who collected the data, who processed and interpreted the results from the monitoring, and who carried out the management interventions emanating from the monitoring.

While monitoring scheme types A and E are easy to distinguish, types B, C, and D may superficially resemble each other as they all involve scientists and local stakeholders. They are different in practice, however. Monitoring schemes of type D are mostly long-running "citizen science" projects (34.6% >10 years; $n = 26$) from Europe and North America (70.4%; $n = 27$). In contrast, most of the schemes of type B and C have been in operation for a short time (<10 years; B: 100%, $n = 13$; C: 85.7%, $n = 14$), are located in the tropics (B: 92.3%, $n = 13$; C: 62.5%; $n = 16$), are more "participatory" (Chambers *et al.* 1989) in character, and typically developed as part of "adaptive management" (Berkes *et al.* 2000).

Regarding issues addressed by different monitoring approaches, the five types of monitoring schemes address different issues (Figure 2a, b). Monitoring scheme type A, B, and C generally monitor products that support local livelihoods (e.g., food, building materials, fuel, water, income) ($P < 0.01$). Conversely, monitoring schemes of type D and E collect data relevant to the conservation of threatened species or populations ($P < 0.01$). Governance also varies between different approaches (Figure 2c). Scientist-executed schemes are located in protected and nonprotected areas (type E schemes; $n = 42$), whereas autonomous local schemes are all located in nonprotected areas (type A schemes; $n = 6$). Monitoring schemes of type C and D are mainly located in nonprotected areas, and schemes of type B are equally distributed in nonprotected areas or in reserves managed by local communities or government (monitoring scheme types B, C, and D; $n = 13$, 16, and 27; respectively).

When applied to the indicators of international environmental agreements, almost all (99%) of the 186 indicators can be measured by professional scientists without involving local stakeholders (Table 2); our type E. At the other extreme, 23% of the indicators can be measured by local stakeholders autonomously without any involvement of professional scientists (Table 2); our type A. However, because type A schemes are self-established

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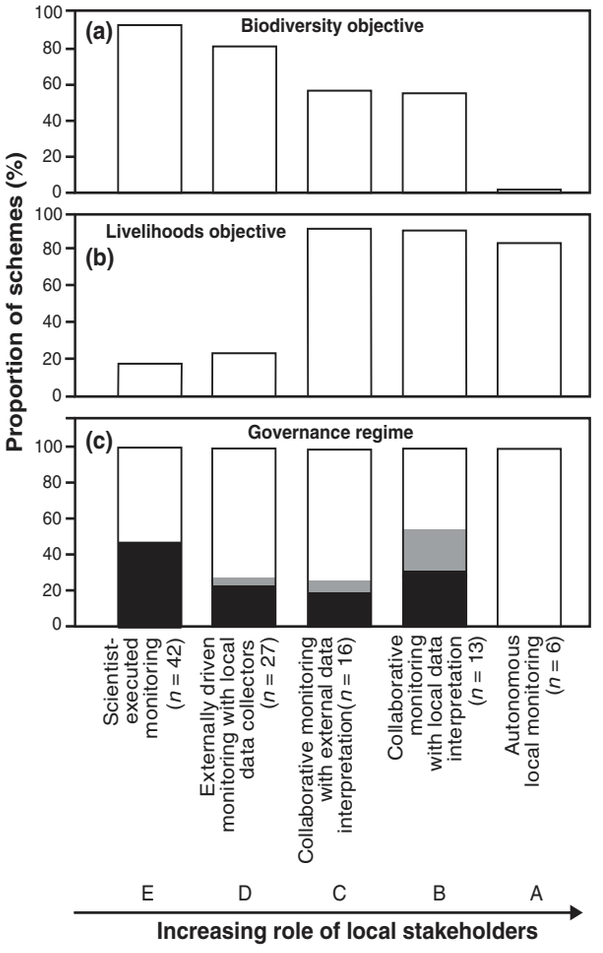

Figure 2 The proportion of published environmental monitoring schemes within each type of monitoring scheme that have a biodiversity (a) or livelihoods (b) objective; and the types of governance regime (c) they operate within, including areas without protection status (white), government-managed protected areas (black), and community-managed protected areas (shaded). The relative role of local stakeholders in the monitoring schemes increases from left to right.

and managed, they would be unlikely to provide data for tracking international environmental agreements.

Our assessment suggests that 63% of the indicators could benefit from local stakeholder involvement in data collection (type C-D schemes; $n = 186$), whereas for 44% of the indicators, local stakeholders might contribute data *and* analysis (type B schemes; $n = 186$; see Table 2). For 92% of the indicators, we could name specific or closely related examples of monitoring schemes ($n = 186$; Table 2), which we interpreted as supporting our results. Thirteen experts, who also assigned our monitoring scheme types to a random sample of the indicators, were in fair agreement with our assignments of suitable monitoring approaches (Kappa coefficient $\kappa = 0.39$; $n = 92$; Appendix S6).

Our assessment of the main constraint to local stakeholder involvement in monitoring international agreements is that much of the work is technically difficult, or requires analytical skills; this relates to 59% of the indicators (Table 2). Another common constraint is that the indicator requires a national overview (45%), or a detailed knowledge of administrative or regulatory aspects in the country (44%). Less frequent constraints are dependence on area-based or remote sensing approaches (16%), or data from museums or herbaria (5%). Our 13 independent experts were in fair agreement with our identification of main constraints to local stakeholder involvement in monitoring the indicators of international agreements ($\kappa = 0.27$; $n = 115$; Appendix S6).

Comparing indicators of environmental agreements with our empirically derived monitoring framework reveals one topic that is particularly suitable to local stakeholder involvement: "ecosystem integrity and ecosystem goods and services" (Table 3). Almost all (94%) indicators of this topic are suitable for local stakeholder involvement in data gathering and most (76%) are suitable for local involvement in data analysis ($n = 17$; Table 3). Making the indicators more appropriate for local stakeholder involvement would require adjusting them to address the challenges: (1) they are technically or analytically demanding (88%; $n = 17$) and (2) they cannot be measured without area-based or remote sensing-based data (29%; $n = 17$; Table 3).

Organizing the 186 indicators of the 12 environmental agreements within the "pressure, state, response" framework (Sparks *et al.* 2011) suggests that indicators of "status" and "pressure" are particularly suitable for data gathering by local stakeholders (80%; $n = 61$; and 71%; $n = 31$; respectively; Appendix S7). Most are also suitable for local stakeholder involvement in data analysis (61%; $n = 61$; and 52%, $n = 31$; respectively; Appendix S7).

Discussion

Our analysis shows that published environmental monitoring schemes range from entirely local efforts—with all the work undertaken by local people—to efforts where monitoring and analysis are undertaken solely by professional researchers. Within this range, schemes fall into five categories defined by the degree of scientist and local participation in scheme design, data collection, data analysis, and implementation of management interventions. Other characteristics, such as the Gross National Income of the country concerned, are not defining parameters.

Despite strong efforts to be objective in this work, some areas remained subjective. These included our selection of parameters for clustering, and the accuracy of data

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extraction from publications. We also relied on the peer-reviewed literature, which may underestimate small-scale local and volunteer-based efforts and are probably biased toward large, well-funded schemes.

Our empirically based, statistical analysis corroborates all five categories previously identified by "experts" (Danielsen *et al.* 2009). The five categories of environmental monitoring schemes show similarities with categories of public participation described in the literature on "community development" (Arnstein 1969; White 1996; Pretty & Hine 1999). Such classifications tend to range from fully local stakeholder-driven approaches to externally led interventions with very little or no local participation. Most monitoring schemes are established to achieve either social or environmental objectives, but schemes of category B and C often aim at attaining both objectives. A major difference exists between the categories of monitoring schemes in terms of why the information is being sought and who are the end-users of the information (Staddon *et al.* 2012). Schemes of the participatory categories (A, B, and C) are mainly "monitoring for participants" to improve their livelihoods (Figure 2). Conversely, scientist-led schemes (type D and E) are "monitoring for others" to protect biodiversity. A clear focus on who and what the monitoring is for may help to avoid establishment of schemes that fall apart when scientists depart by ensuring that the monitoring is of specific value to specific people (Staddon *et al.* 2012).

Jones *et al.* (2011) proposed that the most important global environmental monitoring objectives are: (1) To evaluate conservation management actions; (2) To inform policy choices; and (3) To raise awareness among the public and policy makers of sustainable development. Meeting these objectives requires careful choice of environmental indicators and a clear understanding of the best ways of collecting data to populate them. A major challenge for delivering international environmental agreements is that of linking the agreements to decision-making on the management of natural resources in the "real world." Past lessons suggest that use of "lay" knowledge can help governments and civil society address environmental problems at early stages (Harremoës *et al.* 2001). Empirical studies and reviews of the scientific literature also suggest that involving local stakeholders in monitoring the environment can not only raise awareness among the public and policy makers about sustainable development (e.g., Funder *et al.* in press) but also—crucially—enhance management responses and improve the speed of decision-making to tackle environmental trends at operational levels of resource management (Danielsen *et al.* 2010; Tidball & Krasny 2012).

To inform discussions on investments in effective monitoring of environmental agreements, we compared the

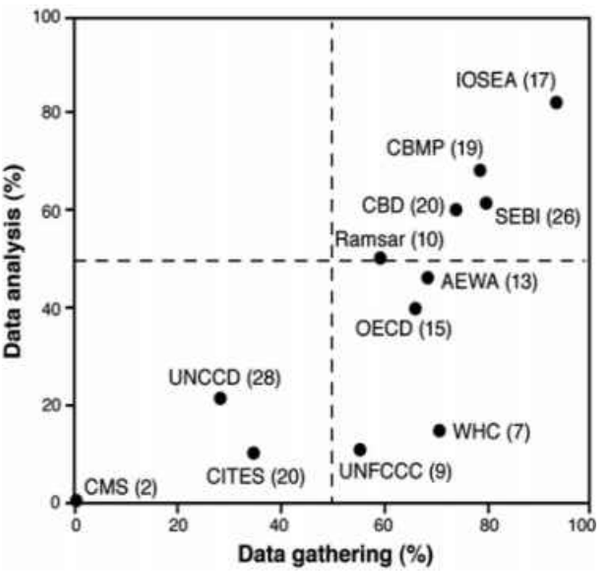

Figure 3 Proportion of indicators from 12 international agreements that are suitable for local stakeholder involvement in data gathering (*x*-axis) and data analysis (*y*-axis). For each agreement, the *x*-axis plots the proportion of indicators that can be measured by professional scientists with the involvement of local stakeholders as data collectors. This indicates the extent to which the agreement is amenable to being monitored by monitoring schemes of type C-D of our framework. The *y*-axis plots the proportion of indicators that can be measured by local stakeholders, who not only collect data but also process and interpret the data and present the findings to decision makers. This indicates the extent to which the agreement is amenable to being monitored by monitoring schemes of type B of our framework. The dashed cross lines indicate 50% values for each axis. Environmental agreements with high values on both axes are most amenable to monitoring approaches with local stakeholder involvement. The number of indicators of each agreement is shown in brackets. For the abbreviations of the international agreements, see Table 2.

proportions of indicators suitable for monitoring schemes of type B and C-D. We classified the environmental agreements into three categories (see the quadrants in Figure 3). Agreements in the upper right quadrant are those that are most suited to involving local stakeholders in *both* collecting and analyzing monitoring data. These agreements are on marine turtle conservation (IOSEA, for abbreviations, see Table 2) and on monitoring biodiversity in Europe (SEBI), the Arctic (CBMP) and globally (CBD). Despite the suitability of these four agreements for local stakeholder-led monitoring, some of their indicators are technically or analytically demanding (Table 2). Environmental agreements in the lower right quadrant are suited to involving local stakeholders in collecting but *not* in analyzing data. These agreements are WHC, AEWA, OECD, Ramsar, and UNFCCC although, for UNFCCC, our assessment is subject to uncertainty (Table 2). Environmental agreements in the lower left quadrant are least suited to involving local stakeholders in collecting or

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Table 4 Examples of indicators of international environmental agreements that are either amenable or not amenable to involvement of local stakeholders in their monitoring

		Examples of indicators	
International agreement[a]	Coverage	That are amenable to involvement of local stakeholders in their monitoring	That are *not* amenable to involvement of local stakeholders in their monitoring
AEWA	Old World	"Trends in waterbird populations"	"€100,000 annually disbursed to developing countries to help implement AEWA"
CBD	Global	"Anthropogenic pressures on coral reefs"	"Biodiversity values have been integrated into poverty reduction strategies"
CBMP	Arctic	"Human Well-being Index"	"Land Cover Change Index"
		"Trends in availability of biodiversity for traditional food"	"Trends in extent of biomes, habitats, and ecosystems"
		"Trends in incidence of pathogens and parasites in wildlife"	"Coverage of protected areas"
		"Trends in phenology"	"Extent of seafloor destruction"
CITES	Global	"Number of cases where CITES regulation has had positive impact on conservation status of species"	"Number of annual export quotas based on population surveys"
IOSEA	Indian Ocean[b]	"Marine turtle population trends, and debris near turtle habitats"	"Genetic identity of marine turtle populations"
OECD	Global	"Fish catch"	"Ozone layer depletion"
		"Intensity of use of water and forest resources"	"Acidification via NOx and SOx emission"
		"Urban environmental quality"	"Toxic contamination by heavy metals and organic compounds"
Ramsar	Global	"Status and trends of waterbird biogeographic populations"	"Status and trends in wetland ecosystem extent"
SEBI	Europe	"Freshwater quality"	"Ecosystem coverage"
		"Forest deadwood"	"Critical load exceedance for nitrogen"
		"Invasive alien species in Europe"	"Ecological Footprint of European countries"
		"Marine Trophic Index of European seas"	"Patent applications based on genetic resources"
UNCCD	Global	"Area of forest under sustainable management"	"Number of countries implementing action plans"
UNFCCC	Global	"Biomass" (e.g., above-ground woody biomass of tropical forests)	"Leaf Area Index"
		"Ocean colour for biological activity"	"Fraction of absorbed photosynthetically active radiation"
		"Sea ice, and snow cover"	"Upper air temperature"

[a]Abbreviations in Table 2.
[b]Africa, Asia, and Australia.

analyzing data for measuring their indicators. These are CITES, UNCCD, and CMS (although CMS has only two indicators). For the agreements in the two lower quadrants, the main constraint to involving local stakeholders is that many of the indicators require a national overview and detailed knowledge of legislative aspects in the countries concerned to be effectively monitored (Table 2).

Our analysis of indicators from environmental agreements suffers from the flaws of using experts to think of examples (Sutherland *et al.* 2004). Although our own assessment of a sample of the indicators obtained the highest Kappa coefficient and thus was the most representative of all the expert assessments, there was only fair agreement between our assessment and the 13 independent assessments, suggesting that individual interpretation of the indicators may have influenced how we coded them (Appendix S6). We found the greatest divergence in individual interpretation for those indicators that were not clearly formulated. In many cases, the indicators are broad headlines without specified metrics. We also assume that the 12 international environmental agreements we examined are representative of international agreements, although other agreements may be more "bottom-up" (e.g., Partnership for the East Asian-Australasian Flyway 2013). We did not evaluate local or subnational environmental policies, which might have more potential for public involvement. Finally, for most of the indicators that are amenable to local stakeholder involvement in monitoring, local stakeholder measurements would be unlikely to stand alone. In most cases, they would need to be used in conjunction with scientist-executed measurements. Nevertheless, our findings demonstrate that, under the present work plans of many international environmental agreements, there is considerable opportunity for involving local stakeholders in collecting relevant data. Table 4 provides examples

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Table 5 Recommendations for NGOs, government agencies, and scientists to help link public participation in scientific research to the indicators and needs of international environmental agreements

Proposed responsible	Proposed action
NGOs and the "citizen science community"	Identify what types of data are not being collected by "citizen science" and "community monitoring" initiatives. Identify what projects the field would need for more comprehensive monitoring of international environmental agreements. Develop list of needed projects for potential donors.
Government agencies and multilateral organizations	When selecting and developing environmental indicators, make sure you have a clear understanding of how the indicators are going to be measured and by whom. Undertake cost-benefit analyses of local stakeholder engagement versus expert approaches to monitoring of indicators. If you aim for local stakeholder involvement in monitoring indicators, avoid indicators that require a national overview or detailed knowledge of administrative or legislative aspects. See examples in Table 4.
Scientists	Develop a new field of research that predicts, and test predictions about, the benefits of environmental monitoring with varying degree of local participation (Possingham *et al.* 2012).

of indicators that are amenable and not amenable to involvement of local stakeholders in their monitoring. The topic "ecosystem integrity and ecosystem goods and services" is probably particularly suitable to local involvement because in many areas, the local communities heavily depend on tangible products like food provided by the natural ecosystems.

As 63% of the existing indicators we examined are suitable for some form of "citizen science" (Shirk *et al.* 2012) or "community-based monitoring" (Fry 2011), this has potential to help international environmental agreements to raise awareness among participants at local, national, and international scales. Efforts to mobilize and maintain a large "citizen science" or "community-based" initiative can, however, be costly and time-consuming. Some indicators are best suited to expert-driven assessment. Great care is therefore needed when developing indicators. To aid this process, we propose a series of recommendations (Table 5). A few agreements, such as the Ramsar Convention on Wetlands of International Importance, already use thousands of volunteers around the world to collect required data on bird populations (Kuijken 2006), which helps to populate the "status and trends of waterbird biogeographic populations" indicator (Appendix S5). In addition, eBird, a project managed at the Cornell Lab of Ornithology, now collects more than 3 million checklists of birds from observers around the globe each month that can be used in a variety of indicators focused on bird populations (Cornell Lab of Ornithology & National Audubon Society 2013). Similarly, a network of volunteers monitors coral reefs worldwide to collect the data required to populate the CBD indicator "anthropogenic pressures on coral reefs [...] are minimized, so as to maintain their integrity and functioning" (WordFishcenter 2008).

In conclusion, our findings suggest that promoting "community-based" and "citizen science" approaches could significantly enrich the monitoring of progress toward the indicators of the CBD and many other global conventions. It would also link environmental monitoring to awareness raising and enhanced decision-making at all levels of resource management.

Acknowledgments

We thank T. Tyrrell and M. Walpole of UNEP-WCMC for information on multilateral environmental agreements. We thank H. Andrianandrasana, A. Crall, S. Gearheard, S. Holt, S. Hvalkof, G. Kerr, J. Massao, T.H. Mwampamba, G. Newman, P. Paaby, C. Prip, D. Schmidt-Vogt, S. Sophat, N. Singh, D. Thomas, T. Vargo, and Z. Yi for examining indicators. This work was funded by the Danish Council for Development Research, the Nordic Council of Ministers, and the European Commission. N.D.B. was supported by the Danish National Research Foundation through the Center for Macroecology, Evolution and Climate and by WWF-US.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Appendix S1. Description of the methods.

Appendix S2. Matrix of the 107 published environmental monitoring schemes scored across 25 parameters.

Appendix S3. Reference list of the published environmental monitoring schemes that were used to develop our statistically defined typology of monitoring approaches.

Appendix S4. Dendrogram of environmental monitoring schemes, based on cluster analysis of 17 parameters among 107 schemes published between 1987 and 2012 showing the identity of each scheme.

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Appendix S5. The data set of 186 indicators within the 12 international environmental agreements.

Appendix S6. Results of 13 experts' independent assignment of our environmental monitoring scheme types to a random sample of 12.5% of the indicators of the 12 international environmental agreements.

Appendix S7. Proportion of indicators among 12 international environmental agreements across the "pressure, state, and response" framework that are suitable for monitoring approaches of type A, B, C-D, and E.

References

Arnstein, S.R. (1969). A ladder of citizen participation. *J. Am. Plann. Assoc.*, **35**, 216-224.

Berkes, F., Colding, J. & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecol. Appl.*, **10**, 1251-1262.

Butchart, S.H.M., Walpole, M., Collen, B. *et al.* (2010). Global biodiversity: indicators of recent declines. *Science*, **328**, 1164-1168.

Chambers, R.G., Pacey, A. & Thrupp, L.A. (1989). *Farmer first: farmer innovation and agricultural research*. Intermediate Technology Publications Ltd., London, UK.

Cinner, J.E. & Aswani, S. (2007). Integrating customary management into marine conservation. *Biol. Conserv.*, **140**, 201-216.

Convention on Biological Diversity. (2013) http://www.cbd.int/ (visited Feb. 15, 2013).

Cornell Lab of Ornithology & National Audubon Society. (2013). *eBird*. http://www.ebird.org (visited Feb. 15, 2013).

Danielsen, F., Burgess, N.D., Balmford, A. *et al.* (2009). Local participation in natural resource monitoring: a characterization of approaches. *Conserv. Biol.*, **23**, 31-42.

Danielsen, F., Burgess, N.D., Jensen, P.M. & Pirhofer-Walzl, K. (2010). Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples involvement. *J. Applied Ecol.*, **47**, 1166-1168.

Danielsen, F., Topp-Jørgensen, E., Levermann, N. *et al.* (2013). Counting what counts: using local knowledge to improve Arctic resource management. *Polar Geog.*, in press.

Ehrlich, P.R. & Kennedy, D. (2005). Millennium assessment of human behavior. *Science*, **309**, 562-563.

Fry, B. (2011). Community forest monitoring in REDD+: the 'M' in MRV? *Environ. Sci. Policy*, **14**, 181-187.

Funder, M., Danielsen, F., Nielsen M.R. *et al.* Reshaping conservation: the social dynamics of participatory monitoring in Tanzania's community-managed forests. *Conserv. Soc.*, in press October 2012.

Harremoës, P., Gee, D., MacGarvin, M. *et al.* (eds.) (2001). *Late lessons from early warnings: The precautionary principle 1896–2000*. Environmental Issue Report 22. European Environment Agency, Copenhagen, Denmark.

Intergovernmental Platform on Biodiversity and Ecosystem Services. (2013) http://www. ipbes.net/ (visited Feb. 15, 2013).

Johannes, R.E. (1998). Government-supported, village-based management of marine resources in Vanuatu. *Ocean Coast. Manage.*, **40**, 165-186.

Jones, J.P.G., Collen, B., Atkinson, G. *et al.* (2011). The why, what, and how of global biodiversity indicators beyond the 2010 target. *Conserv. Biol.*, **25**, 450-457.

Kanie, N. (2007). Governance with multilateral environmental agreements: A healthy or ill-equipped fragmentation? Pages 67–86 in W. Hoffmann, L. Swart, editors. *Global environmental governance*. Center for UN Reform Education, New York.

Kuijken, E. (2006). A short history of waterbird conservation. Pages 52-59 in G.C. Boere, C.A. Galbraith, D.A. Stroud, editors. *Waterbirds around the world*. The Stationery Office, Edinburgh, UK.

Mace, G.M. & Baillie, J.E.M. (2007). The 2010 biodiversity indicators: challenges for science and policy. *Conserv. Biol.*, **21**, 1406-1413.

Mitchell, R.B. (2003). International environmental agreements: a survey of their features, formation, and effects. *Annu. Rev. Environ. Resour.*, **28**, 429-461.

Obura, D.O. (2001). Participatory monitoring of shallow tropical marine fisheries by artisanal fishers in Diani, Kenya. *Bull. Mar. Sci.*, **69**, 777-791.

OECD. (1998). *Towards sustainable development: environmental indicators*. OECD, Paris.

Partnership for the East Asian-Australasian Flyway. (2013). *Partnership for the East Asian-Australasian Flyway*. http://www.eaaflyway.net/ (visited Feb. 15, 2013).

Pattengill-Semmens, C.V. & Semmens, B.X. (1998). Fish census data generated by non-experts in the Flower Garden Banks National Marine Sanctuary. *Gulf Mex. Sci.*, **2**, 196-207.

Pereira, H.M., Ferrier, S., Walters, M. *et al.* (2013). Essential biodiversity variables. *Science*, **339**, 277-278.

Possingham, H.P., Wintle, B.A., Fuller, R.A. & Joseph, L.N. (2012). The conservation return on investment from ecological monitoring. Pages 49–61 in D. Lindenmayer, P. Gibbons, editors. *Biodiversity monitoring in Australia*. CSIRO, Collingwood, Australia.

Pretty, J. & Hine, R. (1999). *Participatory appraisal for community assessment*. Centre for Environment and Society, University of Essex, Essex, UK.

Shirk, J.L., Ballard, H.L., Wilderman, C.C. *et al.* (2012). Public participation in scientific research: a framework for deliberate design. *Ecol. Soc.*, **17**, 29.

Sparks, T.H., Butchart, S.H.M., Balmford, A. *et al.* (2011). Linked indicator sets for addressing biodiversity loss. *Oryx*, **45**, 411-419.

Staddon, S.C., Nightingale, A. & Shrestha, S.K. (2012). Who and what is participatory ecological monitoring for. Pages 164–170 in S.C. Staddon, editor. *Keeping track of nature:*

interdisciplinary insights for participatory ecological monitoring. The University of Edinburgh, Edinburgh, UK.

Sutherland, W.J., Pullin, A.S., Dolman, P.M. & Knight, T.M. (2004). The need for evidence-based conservation. *Trends Ecol. Evol.*, **19**, 305-308.

Tidball, K.G. & Krasny, M. (2012). A role for citizen science in disaster and conflict recovery and resilience. Pages 226–233 in J. L. Dickinson, R. Bonney, editors. *Citizen science*. Cornell Press, Ithaca, NY.

UNEP, CBD. (2010). *UNEP/CBD/COP/DEC/X/2 2010, Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its tenth meeting, Nagoya, Japan, 18–29 October 2010. Decision X/2. The strategic plan for biodiversity 2011–2020 and the Aichi biodiversity targets*. Secretariat of the CBD, Montreal, Canada.

Walker, B., Barrett, S., Polasky, S. *et al.* (2009). Looming global-scale failures and missing institutions. *Science*, **325**, 1345-1346.

Walpole, M., Almond, R.E.A., Besançon, C. *et al.* (2009). Tracking progress toward the 2010 biodiversity target and beyond. *Science*, **325**, 1503-1504.

White, S. (1996). Depoliticising development: the uses and abuses of participation. *Dev. Practice.*, **6**, 6-15.

WordFishcenter. (2008). *Global Coral Reef Monitoring Network*. http://www.gcrmn.org (visited Feb. 15, 2013).

World Bank. (2012). *Countries and economies*. http://data.worldbank.org/country (visited Feb. 25, 2012).

Yoccoz, N.G., Nichols, J.D. & Boulinier, T. (2001). Monitoring of biological diversity in space and time. *Trends Ecol. Evol.*, **16**, 446-453.

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APPENDIX VIII

Danielsen, F., Burgess, N., Funder, M., Blomley, T., Brashares, J., Akida, A., Jensen, A., Mendoza, M., Stuart-Hill, G., Poulsen, M.K., Ramadhani, H., Sam, M.K. and Topp-Jørgensen, E. 2010.
Taking stock of nature in species-rich but economically poor areas: An emerging discipline of locally-based monitoring.
Pg. 88–112 in: *Taking Stock of Nature* (Ed. A. Lawrence). Cambridge Univ. Press, UK.

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5

Taking stock of nature in species-rich but economically poor areas: an emerging discipline of locally based monitoring

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Introduction

Conventional scientist-executed forms of monitoring are expensive and rely upon highly skilled scientists or technicians (Danielsen *et al.*, 2000). As such only a small amount of this type of monitoring is undertaken in developing countries, where funding and available expertise are limited. This is unfortunate as the developing countries have the greatest importance globally in terms of their assemblages of species, including those threatened by extinction, and also have a great diversity of habitats and important ecosystem services (Millenium Ecosystem Assessment, 2005). They are also the parts of the world where habitat loss is currently proceeding at the greatest speed, and where we know least about the trends in species abundance (Balmford, Green and Jenkins, 2003; IUCN, 2007).

Recently, experiments have been made to involve less educated local people in monitoring of natural resources in developing countries. Although there are still a number of scientific questions surrounding these approaches, and many schemes are still at an early stage of development, the new approaches show a great deal of promise (Danielsen, Burgess and Balmford, 2005a; Danielsen, Burgess and Balmford, 2005c). This chapter analyses the success and challenges of four schemes that stand out from the majority, because they have been replicated and scaled-up, and are now institutionalized and adopted nationally in the respective countries. We begin by describing and explaining the

Taking Stock of Nature: Participatory Biodiversity Assessment for Policy, Planning and Practice, ed. Anna Lawrence. Published by Cambridge University Press. © Cambridge University Press 2010.

activities and outcomes for each of the four schemes, before presenting our own cross-cutting analysis of the benefits and challenges of such approaches.

Ranger-based monitoring of Ghana's savannah reserves

What we did and why

The first formal wildlife monitoring in Ghana was established by the British colonial authorities in the early 1900s. At this time, monitoring focused on several hunting reserves which were designated for use only by the colonial elite (Ghana Wildlife Division, 2000). Many West African communities, however, had their own forms of wildlife monitoring which date back hundreds or even thousands of years. For example, in many areas, local chiefs required hunters to provide a leg or other body part of every animal taken on their lands. In this way, chiefs not only received a share of the meat, but were able to monitor the rate of wildlife off-take and implement reductions of harvest if necessary.

Following independence in 1957, Ghana adopted new monitoring policies in protected areas with the stated goal of sustainably managing wildlife resources to allow bushmeat harvest and other benefits to local communities (Ghana Wildlife Division, 2000). This relied on locally based employees of the Ghana Wildlife Division (GWD, initially the Department of Game and Wildlife) to record the type and number of larger vertebrates encountered on monthly walking patrols (Brashares, Arcese and Sam, 2001) and during daily activities around camp. These counts were conducted around ranger posts within at least 11 national parks and resource reserves starting in 1968, and continue in some form in several of these reserves today (Table 5.1). The number of posts in each ranges from two to 31 so the monitoring data can illuminate both temporal and spatial patterns (Brashares and Sam, 2005).

Employees of the GWD were often drawn from local communities and received limited training in animal identification or sampling methods. Parks officials viewed the collection of count data as one means of ensuring that Division staff were active in conducting foot patrols in the field. Staff collected the data because it was part of their job and a metric by which they were evaluated, but the goal was to ensure that wildlife use was sustainable, not to prevent its use altogether (Ghana Wildlife Division, 2000).

The monitoring data were collected regularly over more than 30 years, but were used only for internal, annual wildlife estimates and seldom were fed back into the management of the protected areas from which they came. In 1999, researchers from the GWD and University of California, Berkeley, began to summarize and analyse the data using more quantitative techniques, see

Table 5.1. *Summary characteristics of the locally based natural resource monitoring schemes in Ghana, The Philippines, Tanzania and Namibia*

Country[a]	Biome[b]	Land tenure system[c]	Type of participation by community members[d]	Who compiles data[e]	What is monitored[f]	Spatial scale Total size of area monitored (ha)[g]	Interval between successive bouts of data collection (days)	Community member time spent on data collection (person-hours/ha/yr)	Payment provided to community members involved in the monitoring (USD)	Indicative recurrent costs of monitoring (USD/ha/yr)[h]	Indicative total funding for management (USD/ha/yr)
Ghana	t	PA	II(0)	R	Use/Wildl	516 500(2)	30	No community members involved[i]	No community members involved	0.06 (2003)	0.18[j]
Philippines	t(m, fw)	PA	I(350)	R/C	Use/Wildl	1 090 000 (8)	90	0.005	0 (snacks)	0.04 (2001)	1.75
Tanzania	t	PA/non-PA	I(298)	C	Use/Wildl	144 403 (4)	Varies	0.201	0–2/day	0.05 (2003)[k]	0.23
Namibia	t(fw)	C-PA	I(200)	C	Use/Wildl	7 000 000 (30)	Varies	0.005[l]	100/mth[m]	0.01 (203)[lm]	0.05–0.65[l]

[a]Source of information: Danielsen *et al.*, 2005a, pp. 2512–2513.
[b]t = terrestrial; fw = freshwater; m = marine (bracketed biomes account for a minor portion of the area under monitoring).
[c]C-PA = protected area managed by the local non-PA = outside of protected area; PA = protected area under government authority.
[d]I = Monitoring scheme intended to involve the community members in the local design of the monitoring as well as in data collection, data analysis, data analysis, and monitoring-based decision-making; II = Monitoring scheme not currently intended to involve community members. The number of community members directly involved in the monitoring is indicated in brackets.
[e]C = community members; R = government rangers.
[f]Use = resource use; Wildl = wildlife species/populations and habitats.
[g]The number of areas monitored is indicated in brackets.
[h]Year in brackets; excluding depreciation of equipment.
[i]The rangers however often came from local communities.
[j]This figure includes the costs of monitoring.
[k]Funds generated locally from user fees.
[l]Many conservancies are located in large deserts.
[m]Funds generated locally from trophy hunting or tourism.

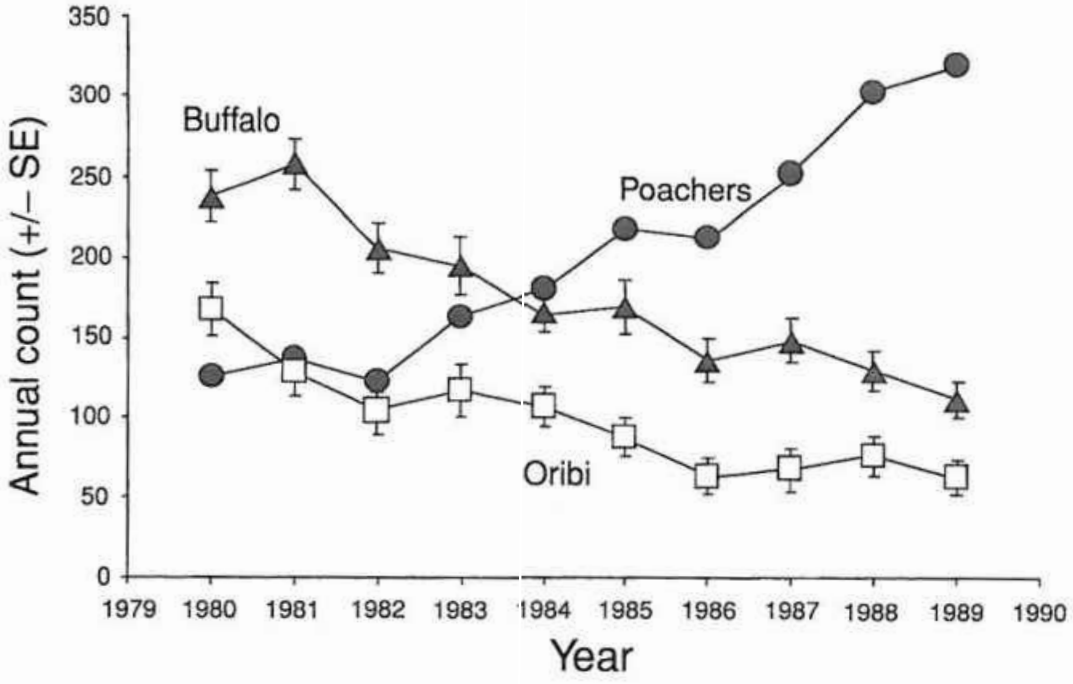

Figure 5.1. Annual counts of African buffalo (*Syncerus caffer*) (▲), oribi antelope (*Ourebia ourebi*) (□) and poachers (●) observed in Mole National Park, 1980–89, based on the locally based natural resource monitoring scheme in Ghana. Each point, except for poacher counts, represents the mean of monthly count totals ±SE. Poacher counts represent the sum of observations across months.

Figure 5.1 (Brashares and Arcese, 2002). Starting around 2001, monitoring efforts were modified and consolidated in a smaller number of defined areas within several of Ghana's parks (B. Volta-Tineh, personal communication). Field staff no longer were based at remote field camps but travelled to defined stations each month from a central park headquarters to conduct patrols and surveys. Today, wildlife data collected from field patrols are summarized in spreadsheets by park personnel and often are consulted by senior park officials when making decisions about focal areas for community outreach or allocation of patrol effort. Thus, these monitoring data are involved in the local decision-making process, and linked directly back to management at the local scale.

What was the outcome and why?

Prior to 1999, count data collected by the GWD were used only sparingly, in the formulation of annual summaries for each protected area, for example to produce species lists for a park or to ascertain whether a given species could be found in a certain region of Ghana. Surprisingly, the data were rarely used in formulating or evaluating management plans and initiatives, despite the value of the spatially explicit data.

Nor has ranger-based wildlife monitoring contributed to management decisions at a national scale. However, this is likely to change in the near future as the government of Ghana and external funding agencies look for ways to quantify the effectiveness of wildlife conservation initiatives. For example, the GWD has begun a programme to facilitate community-based management of wildlife in lands adjacent to protected areas, intended to provide communities with direct benefits from wildlife conservation while also creating habitat buffers around reserves. Measuring the effectiveness of these programmes for maintaining or enhancing wildlife in reserves requires monitoring data collected before, during and after community-based management is implemented. Thanks to its long-term wildlife monitoring efforts, Ghana has exactly those data.

Perhaps because of the more recent collaboration with an international research team, the use of GWD's monitoring data in the past five years has focused on global rather than local issues. The data were analysed to show long-term changes in wildlife abundance in relation to human demography (Brashares *et al.*, 2001). This research revealed for the first time that the density of humans around a protected area is a strong predictor of the rate of local extinction of wildlife within that area. In so doing, it suggested that understanding patterns of human demography may be a key first step in predicting future challenges for managing natural resources. Additional work using these count data showed that wildlife species differ greatly in their sensitivity to human disturbance (Brashares, 2003). Species requiring large areas of contiguous habitat were those most likely to be affected negatively by human development and activities around protected areas.

The long-term nature of the count data also provided a rare glimpse into the factors that affect human reliance on wildlife at a regional scale (Brashares *et al.*, 2004). By comparing changes in wildlife abundance and intensity of hunting across years of high and low fish supply, this research showed that rural people hunted and consumed more wildlife when alternative sources of animal protein were scarce. By identifying links between management of natural resources at such a large scale, this research emphasized the importance of considering the big picture in any conservation or management initiative. The monitoring programme in Ghana also provides a potentially powerful example for initiatives only now starting in other natural areas by illuminating the frequency and intensity of monitoring needed to accurately detect trends in animal populations (Brashares and Sam, 2005). Taken together, these more recent examinations of the monitoring data have inspired evaluation of international policies and conventions (e.g. the role of distant water fishing fleets

in the decline of African fisheries), but they are yet to have a strong effect on natural resource management in Ghana.

Community-based monitoring of Philippine protected forests

What we did and why

Since 1996, protected area staff and community members have kept track of the wildlife and resource use in protected areas in the Philippines, where many people live and depend on protected area resources. Until the 1990s most protected areas in the country existed only on paper, but government was starting to question the effectiveness of the traditional top-down approach to protected area management. In 1992, the National Integrated Protected Area System Act (DENR, 1992) allowed for community participation in protected area management but was supported by little practical experience in how this could be achieved meaningfully.

In 1996–98, the Philippine Protected Areas and Wildlife Bureau (PAWB) of the Department of Environment and Natural Resources (DENR) developed a simple community- and ranger-based scheme for monitoring biodiversity and resource use in protected areas, with support from the World Bank and Danida, over three years. The process involved protected area staff, local non-governmental organizations and protected area communities. Rather than designing the 'ideal' monitoring scheme, it aimed to develop a feasible minimum starting point which could evolve over time as more resources and skilled people become available to manage and monitor biodiversity (Danielsen *et al.*, 2000). It intended to show, at the protected area level, whether or not management interventions in the area are effective in conserving biodiversity, and to enhance the participation of communities in protected area management. It focused on identifying trends in important biodiversity existence and use, to guide action in protected area management. The focus is at the field level, where most day-to-day management decisions are taken. Methods are kept simple and practical, to be easily integrated into other work activities and sustained with the locally available resources (Table 5.1).

The scheme was designed to build upon and strengthen existing community-based resource management systems. In many areas of the Philippines, traditional measures to oversee and manage natural resources still form an important part of the everyday regulation of local natural resource use. For instance, community leaders and 'ordinary' community members regularly discuss and

assess the availability and quality of particular natural resources, and thereby establish a collective overview of the status and trends of these resources. If they perceive a resource to be declining or threatened, they may impose regulations to limit use.

Data were collected by government rangers and volunteer community members. By allowing rangers to participate in field assessments, the scheme encouraged them into the field and improved their capacity for management. Four field methods were used. The *focus group discussion* method involved establishment of volunteer 'Community Monitoring Groups' who collected information on resource use and biodiversity on a regular basis between quarterly discussions with protected area staff. This method was intended to indicate changes in perceived harvest volume per unit effort. The *field diary* method comprised standardized recording of routine observations and records provided by local people of biodiversity and human use of wild flora and fauna by protected area staff in a simple pocketbook during patrols. This method was intended to indicate changes in the relative abundance of species and resource use. The *fixed point photography* method comprised on-the-ground fixed-point photographing of selected hillsides in priority forest blocks at regular intervals. This method was intended to indicate changes in size of vegetation type blocks and in land-use of priority areas. The *line-transect* method comprised line-transect surveys of wildlife and resource use along permanent routes. This method was intended to indicate changes in wildlife population size, human intensity of resource use, and/or shift in range of wildlife and human resource extraction. When the monitoring scheme was designed these four methods were selected because they were field-based, possible to use in areas where 'specialist staff' are lacking, and believed to be cost-effective (Danielsen *et al.*, 2000).

In each park, the monitoring focuses on a list of 10–15 taxa and 5–10 indicators of resource use, selected by local community members together with protected area staff. Data are collected every three months. The protected area staff and community members interpret the data together, and present a small report every quarter to the Management Council of each protected area (copied to PAWB at national level).

The report is structured so as to encourage park staff to both organize, analyse and interpret the data as well as to propose specific conservation management interventions. It includes the dataset, a list of important observations of changes in species and resource use, and a list of proposed management interventions with a description of the issue identified (e.g. 'conversion of forest for farming of vegetables'), the location and the proposed action to be taken by the protected area council (Danielsen *et al.*, 2005b).

PAWB staff are supposed to regularly review the reports and provide feedback to the park staff, to keep errors at an acceptable level and assist the parks when local management interventions need back-up. It was also envisaged that the PAWB staff would extract data to prepare annual reports for the Secretary of the Environment. This work at national level, however, has suffered from under-funding and weak institutional support.

There are several reasons for the weak capacity of DENR. First, there is no programmatic approach in DENR to environment and natural resource management. Most priority setting is short term and politically or even individually driven, and shifts with the appointment of the departmental Secretaries. In recent years, the average terms of the Secretaries have been only one year. The rapidly shifting priorities have a serious impact on the follow-up and sustainability of longer-term efforts such as monitoring of natural resources. Second, the institutional structure of DENR and the roles and responsibilities of the staff are unclear and ambiguous. There is no single unit in charge of natural resource monitoring, and regularly staff supposed to be in the main responsible for the implementation of the Department's monitoring efforts are simultaneously assigned to perform a multitude of other tasks. Other key reasons include frequent re-assignments of trained staff, and lack of a results-oriented staff performance monitoring and incentive system.

What was the outcome and why?

Although direct project support ceased in 2001, the scheme continues in most sites where it was established, although efforts depend on staff availability and budgets. The government has made it mandatory for their staff to use the scheme as a management tool in protected areas (DENR, 2000) and, as a result, the scheme has spread to new sites. Some NGOs have on their own initiative begun using the scheme. There is, however, a need for further training of park staff in participatory approaches, as well as in species identification, data analysis and application of the field methods in aquatic habitats. At the national level, there is a need to build further capacity in effectively making the locally derived data available to national policy-makers.

The conservation management interventions arising from this scheme have been examined (Danielsen *et al.*, 2005b; Table 5.2). Before this monitoring scheme was established, there was little collaboration between local people and park authorities, and park monitoring was restricted to assessments of the quantity of extracted timber. As a result of two-and-a-half years of operation of the scheme by 97 rangers and 350 community volunteers, 156 interventions were undertaken in eight protected areas (Figure 5.2).

Table 5.2. *Examples of monitoring results and conservation management interventions resulting from the locally based natural resource monitoring scheme in the Philippines (Danielsen* et al., *2007)*

Monitoring method	Example of monitoring result	Conservation management intervention emanating from the monitoring result
Focus group discussion	A community monitoring group reported a decline in the abundance of marine fish in Basco Bay of Batanes Island (Batanes Protected Sea and Landscape).	The municipality of Basco issued an ordinance allowing fishing with hook and line but banning the use of nets and compressors in the bay. The abundance of fish in the bay reportedly increased after only seven months.
Field diary	Reports from local people of sightings of crocodile and the presence of crocodile hunters near San Mariano village (Northern Sierra Madre Natural Park).	The municipality of San Mariano issued an ordinance declaring the critically endangered Philippine crocodile *Crocodylus mindorensis* a municipal 'flagship species' and establishing penalties for violation of previous ordinances intended to protect this species.
Fixed-point photography	A new photo of a forested hill tract in the protected zone of the park showed that a swidden had been opened (Mt Kitanglad Range Natural Park).	Park staff showed the before and after photos to the head of the village. He obtained a promise from the violators not to extend the swidden without permission from the protected area management council.
Line-transect	Fewer records of giant clams (Tridacnidae) than before on the transect swim routes in the sustainable use zone (Apo Reef Natural Park).	The park staff raised awareness among local fishermen of the existing regulations on giant clam collection via the local radio and in person with fishermen when they requested permits to fish inside the park. In addition, staff requested assistance from a university on how to propagate the species and thus restock the wild population.

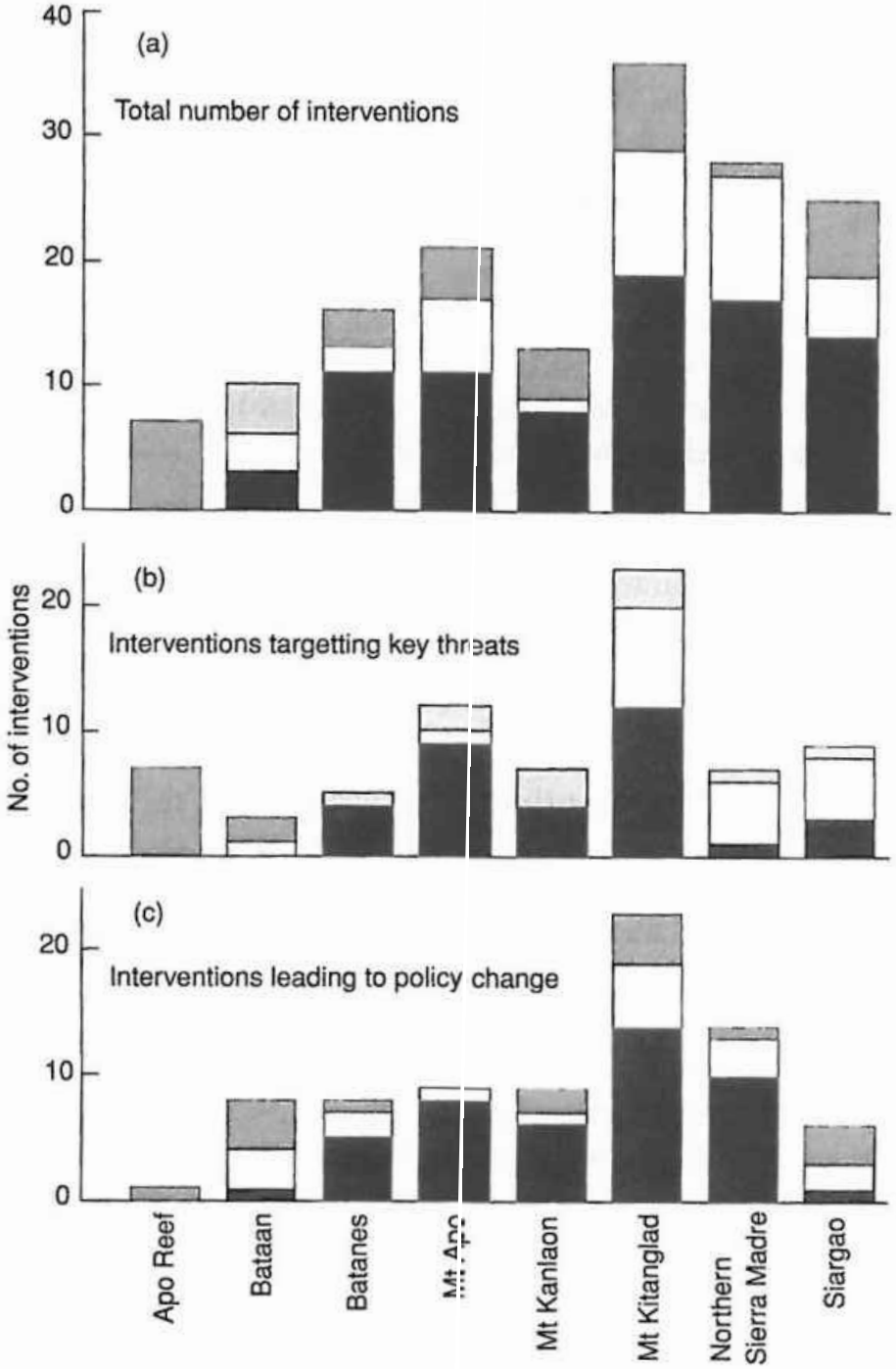

Figure 5.2. Conservation management interventions emanating from the Philippine locally based natural resource monitoring scheme and intended to improve the way local people (black), outsiders (white) and both (grey) manage resources in eight protected areas over two and a half years of operation of the scheme (a). The lower panels show the results if the analysis is restricted to those interventions that only target the three most serious threats to species populations and habitats at each site (b), and those interventions that led to policy change with a potential long-term impact on sustainable development (i.e. new resolutions or bylaws) (c).

To analyse the effectiveness of outcomes, we defined 'meaningful and justified interventions' as those with rational objectives, according to the socio-cultural, ecological and administrative contexts, and appropriate in terms of target, intensity, timing and extent (Danielsen *et al.*, 2005b). In total, 98% of these interventions were, or probably were, meaningful and justified, 47% targeted the three most serious threats to biodiversity at the site (see also Figure 5.2b), and 90% were implemented without external support, suggesting that the interventions were relevant and could be sustained over time at the local level. Many of the interventions were jointly undertaken by community members and the management authorities or consisted of local bylaws in support of park management. As a result of the monitoring, indigenous resource use regulation schemes were re-established with government recognition in several parks. The monitoring led to more diversified management responses on the part of the authorities, including a more socially acceptable and effective approach to enforcement.

Community-based monitoring of village forests in Tanzania

What we did and why

Our third example is from Tanzania, where community members record resource extraction and disturbance in village woodlands and forests. Since the early 1990s, the Tanzania forest sector has been undergoing a radical process of decentralization and devolution. A number of donor-funded projects have experimented with different forms of community-based and joint forest management, and these approaches were enshrined in revisions to the forest policy and legislation in 1998 and 2002 (Blomley and Ramadhani, 2006). Currently, mainland Tanzania has one of the most progressive community forestry jurisdictions in Africa as reflected in policy, law and practice (Wily, 2000; Blomley, 2006).

As part of this trend, the Danish government supported a pilot project in Iringa Region between 1999 and 2004 to facilitate Participatory Forest Management in 23 villages, covering 140 000 hectares of highland, evergreen forests and lowland miombo woodlands. The management agreements provide user rights to local communities including rights to collect and spend revenue from sale of natural resources extraction permits. In turn, the Village Natural Resource Committees (VNRC) are the designated forest managers and must demonstrate an ability to manage forest lands to the benefit of their constituents (the community) and in a sustainable manner (to the District Forest Officer).

The project developed a participatory monitoring scheme which does this by feeding data upwards (to district forestry staff), downwards to the wider village community and laterally (to the members of the VNRC). The scheme is built on existing village government structures, and complies with the regulations and legal duties set out in local government and forestry legislations. The aim was to be simple and cost-effective, and empower community managers to more effectively manage their woodland and forest resources (Topp-Jørgensen *et al.*, 2005; Table 5.1).

As the responsible forest managers, the VNRC maintains records of forest patrols, income, expenditure, meetings and any problems encountered. These records are compiled into a monthly summary sheet and forwarded to the district authorities for review and, where necessary, action. They are also used during routine meetings of the VNRCs to inform discussions about management strategies, harvesting volumes, patrol and enforcement and revenue collection. Since the beginning of the scheme it has been important to ensure that information gathered at village level has direct use value for the forest managers themselves – rather than just generating data for higher-level stakeholders. This created local incentives to continue the monitoring system beyond the life of the project.

The government agency responsible for supervising forestry activities in Tanzania, the Forestry and Beekeeping Division, is currently establishing a national monitoring framework as part of the National Forest Programme, that will track national indicators related to forest extent, condition, revenues, harvesting volumes and products as well as the extent of community involvement and benefits arising from participatory forest management systems (United Republic of Tanzania, 2007). Development partners supporting the forest sector in Tanzania (Danida, Ministry of Foreign Affairs of Finland and the World Bank among others) have agreed to abandon project-specific indicators and to embrace these national indicators. Similarly, rather than constructing time-bound and donor-specific monitoring systems, they have agreed to harmonize these efforts by investing in a single, long-term monitoring system which is embedded in existing government institutions (such as the VNRCs, District Councils and the Forestry and Beekeeping Division) and tracking a commonly agreed set of indicators.

The design of this new system, the National Forestry and Beekeeping Database ('NAFOBEDA'), builds strongly on the community-based models described above. Data on forests under the management of community institutions are captured, stored and compiled at the village level by VNRCs and fed through a district platform to a national database (Akida, 2007). The system, which has recently been finalized following extensive pre-testing, will soon

be introduced to an initial 35 districts in the eastern and southern parts of the country through targeted training. District staff will in turn train VNRCs and other village council staff to ensure that data capture is standardized across all participating villages. Data generated at the national level will feed into policy processes such as annual ministerial budgets, annual joint donor reviews of the forestry sector, and higher-level systems tracking progress towards the goals of the Poverty Reduction Strategy (known in Tanzania as the National Strategy for Growth and Reduction of Poverty).

What was the outcome and why?

The community forestry monitoring scheme in Tanzania has operated since 2002 and continues despite the end of direct project support in 2004. Between November 2002 and June 2004, villages in the montane forest areas maintained an average rate of report returns, of 80%, while villages from lowland woodland sites maintained a slightly lower return rate (Topp-Jørgensen *et al.*, 2005). In total, 181 management interventions had been suggested as a result of monitoring and, of these, 131 had been tabled for discussions during routine meetings of the VNRCs (Figure 5.3). Of the 131 issues discussed by the VNRCs, 50% had been approved by the District Forest Officer and subsequently acted upon. Others have not yet been acted on, because they require a modification of the village forest management plan or joint forest management agreement. This process takes time and resources, and involves District staff, who have limited capacity to make changes rapidly.

Assessment of monitoring forms at Iringa District Forest Office in November 2006 showed a decrease compared with previous years (Poulsen *et al.*, 2007). Visits to nine villages, however, showed that they all continued monitoring efforts, albeit at a reduced level in some places.

Monitoring level is linked to incentives, and villages that obtain revenue to compensate local forest managers generally monitor more frequently. Although it has not been observed yet, this may have implications for long-term continuation of the scheme in montane forests where revenue is limited, as only harvest of non-timber products is permitted. Payment for other ecosystem services (e.g. water, biodiversity value, etc.) might be needed to ensure long-term monitoring in biodiversity rich areas with limited resource extraction potential.

Management interventions raised during routine monitoring at village level were analysed to assess whether they addressed 'scientifically identified threats', which in the miombo woodlands include over-harvesting of wood, and in the highland forests include fire and hunting (Figure 5.3b). Of the 23 villages, 21 had suggested management interventions that targeted the most

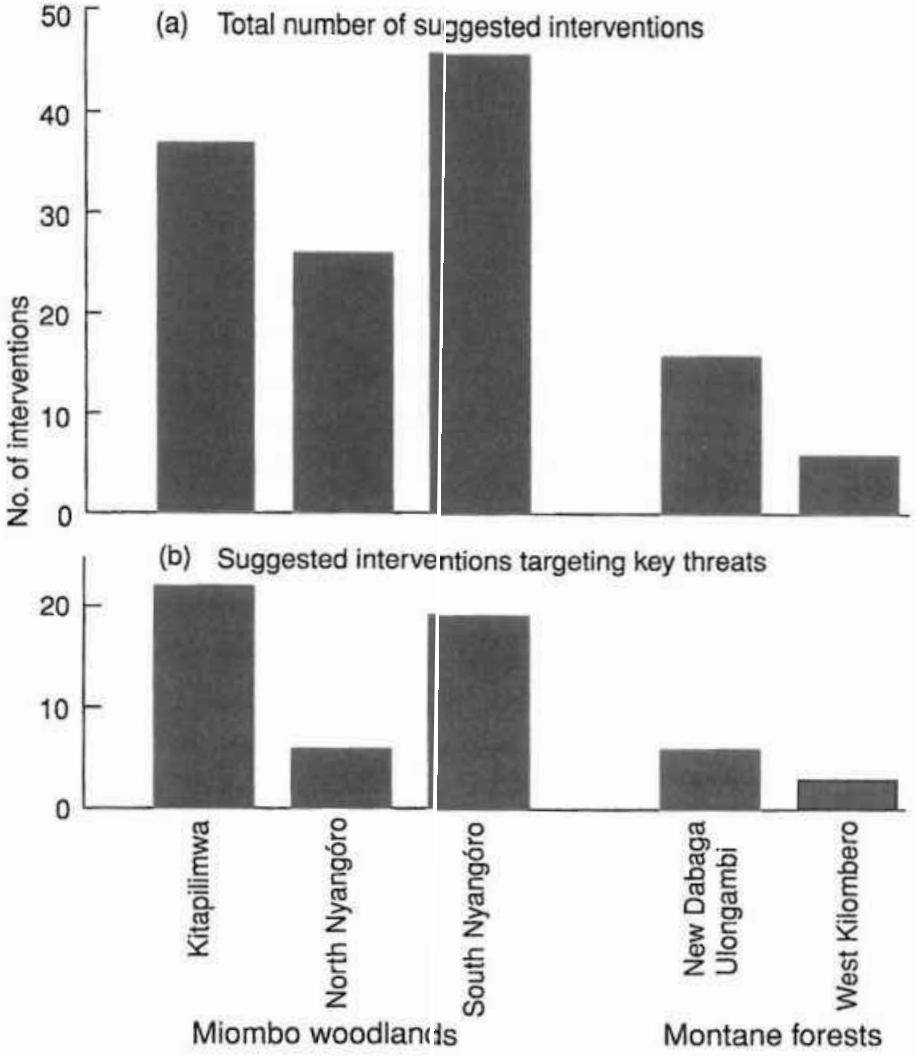

Figure 5.3. Suggested management interventions emanating from the locally based monitoring scheme in miombo woodland and montane forest areas of Tanzania after ten months of operation (a). The lower panel shows the conservation management interventions that only target the most serious threats to species populations and habitats in each area (b). The most serious threats were identified independently; they were wood extraction in the woodlands and hunting and fire in the montane forests.

important threats to their respective forests. Seventy-five percent of interventions targeting the most immediate threats had been implemented while most of the others were awaiting approval by district authorities.

A spin-off benefit from this local monitoring scheme has been its incorporation into the national forestry monitoring scheme described above. When fully operational, this will be the first time in Tanzania that data gathered, compiled and presented by village forest managers have been combined with data gathered by forestry professionals into a single national dataset.

Community-based monitoring of Namibian conservancies

What we did and why

Our final example is from Namibia, where community rangers record various aspects of their conservancy, ranging from wildlife numbers, through economic returns, to infringements of the rules. Namibian legislation provides for the establishment of 'conservancies'. Conservancies can be found in any type of habitat but often comprise large desert areas. Conservancies allow communities on communal land to benefit from wildlife in return for assuming responsibility for the sustainable management of natural resources.

One of the management tools required is a local-level monitoring scheme, to see if objectives are being reached, and to guide any corrective actions. During 2001–2003, and in response to requests for assistance from rural communities, scientists involved in Namibia's Community Based Natural Resource Management programme, with support from USAID, helped conservancies to develop a monitoring scheme known locally as the 'Event Book System'. This is designed to meet the information needs of the local community (Stuart-Hill *et al.*, 2005). Its fundamental principle is that the community decides what they want to monitor, and the technicians respond by facilitating the design (i.e. how to monitor). Conservancy employees collect and analyse the data, and are paid from funds generated locally through trophy hunting or tourism (Table 5.1).

To support the principle of local control, yet provide a rigorous methodology, the monitoring system has over time been modularized by topic, for example: problem animals, poaching, vegetation, predators, and fish. Thus conservancies adopting the system freely select what they want to monitor, and the technical support team then provides a complete kit of Event Book cards for each monitoring topic. No conservancy is ever forced to accept any module and they are free to design their own.

The Event Book is a personalized ring file maintained by each community ranger. The file contains a set of (yellow) cards, one card for each monitoring theme or topic. There is a card for poaching, a card for problem animal incidents, a card for rainfall and so on. As events occur, the ranger selects the appropriate card and records the event. At the end of the month a line is left blank, and the same card used for subsequent events in the ensuing months. At the end of the year, all of the old cards are removed, archived and a fresh set of cards inserted into the book.

It is essential that people collecting the data should also analyse and interpret them, even if the analysis is sub-optimal. This principle emerged through experience with conventional systems, where data sheets are handed over to

external experts, resulting in a loss of ownership, so local people stopped collecting data. Data 'analysis' is simple. There are three types of reporting: monthly incident chart reports; annual reporting maps; and long-term trend-chart reports. On a monthly basis, all field rangers collectively complete the monthly (blue) reporting charts by colouring in boxes indicating the total number of incidents for the month (generally, one observation = one box). Incidents are recorded by hand onto the reporting map using different symbols to differentiate between types of incidents.

At the end of each year, the totals for the year are transferred onto the long-term trend (red) reporting charts. The essential difference between the 'blue' and 'red' cards is that the *x*-axis on the latter is years rather than months. Colour coding the different reporting timescales has proved to be important to avoid confusion by semi-literate community members.

The entire system is paper-based. All papers are filed in a specialized filing box, indispensable where conservancies often have no office. Such a simple, hard-copy based system is critical in remote environments where advanced computer technology is not realistically viable.

However, whilst primarily designed and managed to meet local information needs, the system also provides input to data analysis and decision-making at national level. Each year data are copied during an annual review of each conservancy and are captured within a national monitoring and evaluation database. This database belongs to the Ministry of Environment and Tourism and is used by the government and the Namibian Association of Conservancy Support Organizations to guide strategic decisions such as setting quotas, allocating technical support, and monitoring compliance.

Original raw data never leave the community. This is a key principle when data are extracted beyond the individual conservancy. The data are archived by the conservancy, and copied from paper into digital format for central storage and analysis, thereby allowing more sophisticated analysis by scientists. All data also have a spatial element and are used within a national GIS system for national map-based reporting and analysis.

What was the outcome and why?

More than 44 communal conservancies covering more than seven million hectares have adopted the Event Book System. In 2004 the Namibian Ministry of Environment and Tourism officially adopted the same approach for its national protected areas, and the scheme is also beginning to be used in neighbouring countries.

At the local level, a number of management decisions have arisen from the scheme. One of the most significant results is improved understanding and communication between community members. For example, communities have felt that lion *Panthera leo* represented the greatest threat to their livestock but the data have shown that hyaena *Hyaena* sp. and cheetah *Acinonyx jubatus* cause much more damage. This has influenced their strategies for dealing with problem animals, with the result that fewer livestock are lost to predators. Most of the conservancies use the data for setting sustainable wildlife harvesting quotas. One conservancy decided to move its crop lands away from a flood plain with the almost immediate result that crop damage incidents were reduced to a third of previous years. In a number of conservancies, declining population trends in certain species have prompted them to improve their patrolling activities.

At national level, the government and NGOs have used data from Event Books to inform decisions including:

- allocation of regional wildlife harvest quotas of high value species (elephant);
- design of problem animal compensation schemes;
- compliance reporting of conservancies to government, e.g. showing that the annual harvest of various wildlife species is within sustainable limits;
- displaying community commitment to conservation to satisfy private sector and donor investment;
- allocation of technical and financial support to different communities;
- contribution to a national State of Conservancies Report;
- supporting Namibia and Botswana's case for limited trade in ivory at the meeting of the Convention on International Trade in Endangered Species (CITES) in 2002.

The potential for positive developments from locally based monitoring

A number of lessons have emerged from these four case studies, and other locally based monitoring schemes in developing countries. We summarize these below and offer some suggestions on what further research is required to fully evaluate the effectiveness of this strategy for monitoring natural resource values in developing countries. We base our structured overview of the key lessons on a recently proposed typology of monitoring, from conventional scientist-executed approaches through to those fully owned by local communities (Table 5.3).

Table 5.3. *Summary of different types of monitoring approaches (adapted from Danielsen* et al., *2009)*

Category	Main characteristics	Primary data gatherers	Primary data users
1. Externally driven professional-researcher executed monitoring	External monitoring undertaken by professional researchers. Accuracy and precision may be high, but link to local decisions and empowerment is weak	Professional researchers	Professional researchers
2. Externally driven monitoring with local volunteers or employees	Partly external monitoring that involves either paid staff or unpaid volunteers to collect the data. Analysis undertaken away from area of data collection	Professional researchers, volunteers, paid staff	Professional researchers
3. Collaborative monitoring with external data interpretation	Local stakeholders involved with collecting the monitoring data but data are then analysed elsewhere	Local people with professional researcher advice	Local people and professional researchers
4. Collaborative monitoring with local data interpretation	Local stakeholders involved with monitoring and data analysis, but design provided by outsiders	Local people with professional researcher advice	Local people
5. Autonomous local monitoring	All steps of the monitoring and design undertaken locally	Local people	Local people

In this typology, the ranger-based monitoring scheme in Ghana can be categorised as a category-2 'employee monitoring scheme' because the primary data gatherers are paid staff and the analysis of data is undertaken by scientists away from the area of data collection. The community-based monitoring schemes in the Philippines, Namibia and Tanzania can all be categorized as category-4 'collaborative monitoring schemes with local data interpretation' because the data gatherers are local people supported by advice from scientists, and the primary users of data are local people.

There is a great difference between these categories in terms of results and effectiveness. As participation progresses from category-2 to category-5 monitoring schemes, there is less control over who collects the data, and hence who is trained by outsiders and by how much. But as participation increases there is also an increase in local interest and relevance. Therefore, while one might expect an inverted relationship between accuracy and participation, this is not *necessarily* true, although this needs further research.

Here, we examine five factors that we consider important to making a monitoring scheme relevant and useful: costs, ability to detect trends, promptness of decision-making, potential for local empowerment, and ease of feeding into national and international schemes.

Cost to local stakeholders

Locally based monitoring incurs a significant cost to local people, although resources can also be provided by external agencies. Local time input in the cases described from the Philippines, Tanzania and Namibia varied from 0.01 to 0.20 person-hours per hectare per year (Table 5.1). Available data indicates a median time input of around 0.04 person-hours per hectare per year for locally based monitoring in eight developing countries (Danielsen *et al.*, 2005a). In fully locally based monitoring (with no external involvement) the costs may be considerable, especially when measured against the overall economy of the area. Costs and benefits to local communities therefore need to be considered in the design of local monitoring to ensure a fair workload in relation to local incentives.

Careful design may reduce costs to local stakeholders in locally based monitoring with external input, e.g. by locating monitoring sites in carefully selected but easily accessible areas. There is an abundant literature on how this might be achieved (e.g. Bibby *et al.*, 2000), but as the level of engagement by scientists declines, so does the potential to influence the design of the monitoring programme and thus minimize the costs while maximizing information quality.

Another cost is that of obtaining the relevant expertise to undertake the work. Often this is provided through training by outsiders, but in other cases it is internalized. The expertise required at local level can become considerable, especially where species that are difficult to identify need to be monitored.

Cost to others

As monitoring becomes increasingly locally based then the costs to others of implementation declines. The schemes in our four examples each had recurrent costs of USD 0.01–0.06 per hectare per year to the government and NGOs (Table 5.1). In the most locally based schemes (autonomous local schemes) there are no costs to external people as no external expertise is involved.

There are a variety of different requirements for external expertise during the establishment and training phase of a monitoring programme, as compared with the requirements during implementation. In locally based monitoring the engagement in day-to-day implementation declines and necessary skills relate more to participatory approaches and empowerment. For category-4 schemes there is a need to combine both science (e.g. from foresters and biologists) with social science (sociologists and anthropologists). Careful design might reduce the level of external skill required to instigate a locally based monitoring scheme and ensure it is sustainable.

Accuracy and precision

Local stakeholders typically favour monitoring schemes that are effective, in that the minimum amount of work provides the maximum benefit in terms of taking informed decisions. Accuracy is, however, important because it is necessary for the results to be as robust and defensible as possible.

Currently there is little literature on accuracy and precision within locally based monitoring schemes. An assessment of a locally based marine scheme in the Philippines found that out of four community-collected measures (of reef-benthic cover and fish abundance), only one was correlated with the equivalent data collected by professional biologists, with local stakeholders' measures of fish abundance being far more variable than those of professionals (Uychiaoco *et al.*, 2005). This indicates an urgent need for scientific comparisons of the accuracy and precision of locally based schemes.

Through careful training and sampling design, it should be possible for locally based monitoring to yield results which are as reliable as those of conventional techniques (Yoccoz, Nichols and Boulinier, 2003), and which can shed light on aspects of biodiversity which are hard to monitor conventionally.

To ensure this, it is necessary to consider likely biases at the design stage, to plan sampling effort to minimize their impact, and to train data gatherers and data interpreters accordingly.

Promptness of decision-making

Part of the reason for monitoring natural resources is to inform policy- and decision-makers and to facilitate management interventions. We looked for prior studies on the speed of decision-making in monitoring schemes but found little information. To our knowledge, only the scheme in the example from the Philippines has examined the speed with which conservation management decisions were taken by assessing the time from data sampling to decision-making for each of 156 conservation management interventions (Danielsen *et al.*, 2005b). The mean time from sampling to decision-making in this scheme was only 97 days, probably because most (82%) of the interventions were initiated by the same people and institutions that had compiled the underlying data, sidestepping multilayered bureaucracies.

To obtain the full benefit of rapid decision-making linked to locally based monitoring also requires a supportive policy and legal environment. If local stakeholders have no ownership or control over resources, their monitoring is unlikely to lead to prompt decision-making. Features such as corruption and hidden political agendas may constrain the speed and direction of local decision-making. Careful design may improve the speed of decision-making of all categories of schemes, and in particular, each scheme needs a mechanism for feeding results from the monitoring directly into management.

Potential for local empowerment

Monitoring alone does not empower people, but locally based monitoring can be integrated with processes of local empowerment in natural resource management. This includes the application and generation of local knowledge, and greater influence on and involvement in management decisions. Locally based monitoring should be coupled to local stakeholder's rights and responsibilities, which can be set up by appropriate negotiated agreements. This also helps ensure real local interest in local monitoring.

Few quantitative data exist on the empowerment potential of monitoring schemes. In the scheme in the Philippines, one in three conservation management interventions was jointly undertaken by local community members and government authorities (F. Danielsen, unpublished data). In the Tanzanian scheme, 50% of suggested management interventions were implemented by

the communities themselves (Topp-Jørgensen *et al.*, 2005). Overall, the potential for local empowerment rises with the involvement of local stakeholders in monitoring.

Ease of feeding into national and international schemes

The ability of monitoring schemes to contribute data to national and global schemes probably declines as they become more local. Data from locally based monitoring are beginning to be aggregated for national-level analysis in the examples in the Philippines, Tanzania and Namibia. These initiatives, although promising, are still in their infancy. If well done, they can bring government and communities together in a new way, improve co-ordination and decision-making, clarify roles in broader natural resource management, and raise the profile of Community Based Natural Resource Management efforts among policy-makers and scientists, as datasets are aggregated and presented in wider fora.

Analytical tools such as meta-analysis (Gurevitch, Curtis and Jones, 2001) offer substantial opportunities for analysing data from locally based sources, to provide input into tracking larger-scale trends in the status of populations and habitats (e.g. Loh *et al.*, 2005), the services they provide, and the threats they face. To do this, schemes need to use a small number of methods, each well replicated, across a large number of sites (e.g. Côté *et al.*, 2005).

Research needs

Our study shows the need for rigorous comparisons between locally based and conventional scientist-based monitoring methods. Since the conference on locally based monitoring in Denmark in 2004, a new project has been funded by the Danish Government – 'Monitoring Matters: Comparative Analysis of Innovative Approaches' (MOMA). This project is working in six countries – Ghana, Madagascar, Namibia, Nicaragua, Tanzania and the Philippines (Danielsen *et al.*, 2005c). The aim of the project is to answer some of the basic scientific questions about the importance of locally based monitoring, particularly whether locally based monitoring is able to detect changes in the abundance, distribution and utilization of resources, and whether this approach is an effective resource management tool, when compared with conventional methods.

It would, however, be a mistake to see this approach as an untested pipe dream. Locally based monitoring is already underway, and methods are being further improved. We believe the approach holds promise, but it requires rigorous testing to determine whether local people are best able to monitor changes

in habitat, large animal abundances, cryptic species changes, or changes in ecosystem services. Already some important lessons have emerged from the case studies we highlight in this chapter and we expect more as the schemes mature and ways are found to embed them at the local level and within the systems of governments in developing countries.

Acknowledgements

Our thanks to Andrew Balmford, Leon Bennun, Paul Donald, Martin Enghoff, Jon Fjeldså, Hanne Hübertz, Sune Holt, Per Moestrup Jensen, Julia Jones, Anna Lawrence and Thomas Skielboe for discussion; to the Protected Area and Wildlife Bureau of the Philippine Department of Environment and Natural Resources and the Forestry and Beekeeping Division of the Ministry of Natural Resources and Tourism in Tanzania for collaborative work on locally based monitoring; and to the Research Council of the Danish Ministry of Foreign Affairs, for funding the preparation of this chapter.

REFERENCES

Akida, A. (2007). What is the National Forestry and Beekeeping Database? *The Arc Journal* **21** (September 2007), 34–35.

Balmford, A., Green, R. E. and Jenkins, M. (2003). Measuring the changing state of nature. *Trends in Ecology and Evolution* **18**, 326–330.

Bibby C. J., Burgess, N. D., Hill, D. A. and Mustoe, S. (2000). *Bird Census Techniques*: 2nd edition. London: Academic Press, 350 pp.

Blomley, T. (2006). Mainstreaming participatory forestry within the local government reform process in Tanzania. *Gatekeeper Series* **128**. London: International Institute for Environment and Development.

Blomley, T and Ramadhani, H. (2006). Going to scale with Participatory Forest Management: early lessons from Tanzania. *International Forestry Review* **8**, 93–100.

Brashares, J. S. (2003). Behavioral, ecological, and life-history correlates of mammal extinctions in West Africa. *Conservation Biology* **17**, 733–743.

Brashares, J. S. and Arcese, P. (2002). Role of forage, habitat and predation in the behavioral plasticity of a small African antelope. *Journal of Animal Ecology* **71**, 626–638.

Brashares, J. S. and Sam, M. K. (2005). How much is enough? Estimating the minimum sampling required for effective monitoring of African reserves. *Biodiversity and Conservation* **14**, 2709–2722. Available at www.monitoringmatters.org/articles/full10.pdf.

Brashares, J. S., Arcese, P. and Sam, M. K. (2001). Human demography and reserve size predict wildlife extinction in West Africa. *Proceedings Royal Society of London B* **268**, 2473–2478.

Brashares, J. S., Arcese, P., Sam, M. K. *et al.* (2004). Bushmeat hunting, wildlife declines and fish supply in West Africa. *Science* **306**, 1180–1183.

Côté, I. M., Gill, J. A., Gardner, T. A. and Watkinson, A. R. (2005). Measuring coral reef decline through meta-analysis. *Philosophical Transactions of the Royal Society of London B* **360**, 385–395.

Danielsen, F., Balete, D. S., Poulsen, M. K. *et al.* (2000). A simple system for monitoring biodiversity in protected areas of a developing country. *Biodiversity and Conservation* **9**, 1671–1705.

Danielsen, F., Burgess, N. D. and Balmford, A. (2005a). Monitoring matters: examining the potential of locally-based approaches. *Biodiversity and Conservation* **14**, 2507–2542. Available at www.monitoringmatters.org/articles/full1.pdf.

Danielsen, F., Jensen, A. E., Alviola, P. A. *et al.* (2005b). Does monitoring matter? A quantitative assessment of management decisions from locally-based monitoring of protected areas. *Biodiversity and Conservation* **14**, 2633–2652. Available at www.monitoringmatters.org/articles/full6.pdf.

Danielsen, F., Burgess, N. D. and Balmford, A. (eds.) (2005c). Monitoring matters: examining the potential of locally-based approaches. Fifteen case studies presented in *Special issue of Biodiversity and Conservation* **14**, (11), Available at http://www.monitoringmatters.org/cases.htm

Danielsen, F., Mendoza, M. M., Tagtag, A. *et al.* (2007). Increasing conservation management action by involving local stakeholders in natural resource monitoring. *Ambio* **36**, 566–570.

Danielsen, F., Burgess, N. D., Balmford, A. *et al.* (2009). Local participation in natural resource monitoring: a characterization of approaches. *Conservation Biology* **23**, 31–42. Available at http://www.monitoringmatters.org/cases.htm

Department of Environment and Natural Resources (DENR) (1992). National Integrated Protected Area System Act R. A. No. 7586 and Implementing Rules and Regulations DAO 25, Series of 1992. Manila, The Philippines: DENR, PAWB.

DENR (2000). Guidelines on the Implementation of the Biodiversity Monitoring System (BMS) in Protected Areas. Department of Environment and Natural Resources Administrative Order No. 2000–13. Quezon City, The Philippines: DENR, Diliman.

Ghana Wildlife Division (2000). *Wildlife Division Policy for Collaborative Community Based Wildlife Management*. Accra, Ghana: Ministry of Forestry, 11pp.

Gurevitch, J., Curtis, P. S. and Jones, M. H. (2001). Meta-analysis in ecology. *Advances in Ecological Research* **32**, 199–247.

IUCN (2007). *2007 IUCN Red List of Threatened Species*. Available at www.iucnredlist.org

Loh, J., Green, R. E., Ricketts, T. *et al.* (2005). The Living Planet Index: using species population time series to track trends in biodiversity. *Philosophical Transactions of the Royal Society of London B*, **360**, 289–295.

Millenium Ecosystem Assessment (2005). *Ecosystems and Human Well-Being: Synthesis Report*. Washington D.C: Island Press.

Poulsen, M. K., Massao, J., Burgess, N. and Topp-Jørgensen, E. (2007). Community based monitoring of PFM in Tanzania: initial experiences and lessons learned. *The Arc Journal* **21**, 31–33.

Stuart-Hill, G., Diggle, R., Munali, B., Tagg, J. and Ward, D. (2005). The Event Book System: a community based natural resource monitoring system from Namibia. *Biodiversity and Conservation* **14**, 2611–2631. Available at www.monitoringmatters.org/articles/full5.pdf.

Topp-Jørgensen, E., Poulsen, M. K., Lund, J. F. and Massao, J. F. (2005). Community-based monitoring of natural resource use and forest quality in montane forests and miombo woodlands in Iringa District, Tanzania. *Biodiversity and Conservation* **14**, 2653–2677. Available at www.monitoringmatters.org/articles/full7.pdf.

United Republic of Tanzania (2007). National Forest and Beekeeping Programme Monitoring Database (NAFOBEDA) Version 2.8. Monitoring Manual – Monitoring Procedures. Tanzania: Forestry and Beekeeping Division, Ministry of Natural Resources and Tourism.

Uychiaoco, A. J., Arceo, H. O., Green, S. J. *et al.* (2005). Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. *Biodiversity and Conservation* **14**, 2775–2794. Available at www.monitoringmatters.org/articles/full14.pdf.

Wily, L. A. (2000). Forest law in Eastern and Southern Africa. Moving towards a community based forest future? *Unasylva* **203**, 29 pp.

Yoccoz, N. G., Nichols, J. D. and Boulinier, T. (2003). Monitoring of biological diversity – a response to Danielsen *et al.* *Oryx* **37**, 410.

APPENDIX IX

Funder, M., **Danielsen, F.**, Ngaga, Y., Nielsen, M.R. and Poulsen, M.K. 2013.
Reshaping conservation: The social dynamics of participatory monitoring in Tanzania's community-managed forests.
Conservation and Society 11: 218–232.

Conservation and Society 11(3): 218-232, 2013

Article

Reshaping Conservation: The Social Dynamics of Participatory Monitoring in Tanzania's Community-managed Forests

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Abstract

Drawing on a study of community-managed forest reserves in southern Tanzania, this article discusses how community members engage and shape inclusive protected area management practices to produce outcomes that were not intended by external implementers. The article shows how a participatory natural resource monitoring scheme operating in the area becomes part of the villagers' collective and individual efforts to assert their claims to territory and resources *vis-a-vis* the state, other communities, and other community members. By altering the monitoring procedures in subtle ways, community members strengthen the monitoring practices to their advantage, and to some extent move them beyond the reach of government agencies and conservation and development practitioners. This has led to outcomes that are of greater social and strategic value to communities than the original 'planned' benefits, although the monitoring scheme has also to some extent become dominated by local 'conservation elites' who negotiate the terrain between the state and other community members. Our findings suggest that we need to move beyond simplistic assumptions of community strategies and incentives in participatory conservation and allow for more adaptive and politically explicit governance spaces in protected area management.

Keywords: protected area management, forest management, participation, incentives, monitoring, Tanzania

INTRODUCTION

In the past three decades, inclusive approaches to protected area management have become widespread and a variety of schemes for participatory management of forest and wildlife areas have been implemented worldwide (McShane and Wells 2004; Borrini-Feyerabend et al. 2007; World Bank 2008). Initially, such schemes tended to see people in local communities only as 'beneficiaries' of externally implemented conservation interventions. Later, communities were provided with a more active role as 'participants' in the everyday implementation of conservation measures on the ground, but with only limited influence on decision-making. More recently, there has been an attempt to move away from these fairly instrumentalist notions of participation, towards a greater emphasis on communities as actual 'partners' who collaborate and share decision-making power with the state in co-management schemes[1].

Alongside the evolving role of local communities in protected area management, there has been increasing attention to the notion that if communities are to engage in conservation efforts, they must be provided with tangible incentives that support their livelihoods.

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	DOI: **********

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Such incentives may include financial benefits which are reallocated for local social development purposes, as well as use rights for selected wildlife and forest resources. Some approaches to the ongoing development of a global scheme for Reduced Emissions from Deforestation and Degradation (REDD+) reflect a similar notion, whereby communities may be financially compensated for forest conservation and restoration in order to reduce emissions (UNFCCC 2010).

Yet despite widespread implementation of and support to such schemes, our knowledge is still limited on the ways in which community members actually respond to and engage with participatory approaches in conservation, and what benefits they obtain from this. This article seeks to contribute to our understanding of these matters through a case study of a participatory forest and wildlife monitoring scheme operating in community-managed forest reserves in southern Tanzania. Other studies of this scheme have focused on the efficiency of the monitoring system in terms of providing reliable data on forest and wildlife trends as a basis for management decisions (Danielsen et al. 2011; Nielsen and Lund 2012; Danielsen et al. In press). The current article takes a more in-depth look at the social dynamics of the participatory monitoring system in question. The emphasis here is therefore not on whether the monitoring system is accurate and efficient as a conservation tool[2]. Instead, we examine the forest and wildlife monitoring system as a case study of the ways in which a participatory conservation intervention may be reshaped by community members on the ground, and discuss what this implies for how we understand and implement participatory conservation measures.

Specifically, we show how community members in the study area employ an otherwise mundane monitoring scheme as a means of seeking greater territorial and individual control over forest and wildlife resources *vis-a-vis* the state, other communities and other community members. We further show how, in this process, community members seek to move the scheme beyond the aims and control of the government staff and experts who initiated it. In extension of this, we argue for a more nuanced understanding of the ways in which community members respond to participatory conservation schemes. This includes a greater appreciation of the ways in which community members actively seek to influence and reshape conservation interventions on the ground. It further entails an understanding of the interests of community members in participatory conservation schemes as composite and multi-layered, and involving complex relationships with the state, other communities and other community members.

ANALYTICAL APPROACH AND METHODOLOGY

How should we analytically approach and understand the relationship between communities and external actors in protected areas management? Critical analysis of conservation interventions has tended to focus on the power of the state and other external actors to impose protected areas and associated management practices on local communities against their interests (Escobar 1998; West 2006). From such a viewpoint, even ostensibly 'participatory' approaches to conservation may represent little other than a means of co-optation, whereby communities are lured into conservation activities that first and foremost satisfy the "green agendas" of governments and conservationists in ensuring orderly, effective and low-cost conservation (Escobar 1998; Agrawal 2005; Selfa and Endter-Wada 2008). This critique echoes the debate within participation studies more broadly, where even 'well-intended' participatory schemes have been described as dominated by the worldviews of external participation 'experts' who employ imported approaches that inevitably impose particular norms and practices upon the participating subjects (Kothari 2001). Indeed, some authors have likened participatory schemes to Foucault's metaphor of the "Panopticon". Originally conceived in the late eighteenth century by Jeremy Bentham, the "Panopticon" was envisaged as the perfect prison, where inmates would be subject to discrete but invisible forms of external control and surveillance, and would eventually come to discipline themselves, thereby eliminating the need for violence and other more explicit means of domination (Foucault 1995; Kothari 2001).

While such a perspective on participatory schemes may be correct in some instances, it also contains a risk of portraying local communities as little more than helpless victims of conservation interventions. Seeking a more dynamic understanding, our research draws on the notion that project and policy interventions are social arenas where external and local actors engage and interact in struggles over resources, knowledge and institutions (Long 2001;; Nuijten 2005; Cleaver 2012). Such interaction rarely takes place on an equal footing, as powerful actors bring their assets and advantages into play. Nevertheless as emphasised by Giddens (1984), any relationship of power is subject to the dialectics of control, whereby the dominated may act contrary to the expected. As conservation measures are introduced on the ground, they become subject to the everyday practices of local farmers, pastoralists, etc., and thereby almost invariably introduce some room for manoeuvre and efforts to resist external domination. Hence as Scott (1990) has famously shown in another context, there is frequently room for subversion and 'silent resistance' in the face of a powerful state. This may take many forms, including discrete everyday rule-breaking and 'foot-dragging' (Scott 1990; Holmes 2007), or exploiting legal pluralism and institutional fragmentation to serve the livelihood interests of oneself or the group (Juul and Lund 2002).

Conservation interventions involving local communities may thus go through a process of 'localisation' which modifies the outcomes intended by external initiators. This applies to both traditional 'top-down' forms of intervention and to more participatory styles of intervention (Cornwall and Coelho 2007; Funder 2010). This suggests an emphasis on the way local actors shape and reshape the everyday practices of conservation (the 'how' of things). It furthermore requires an understanding of the interests behind these actions i.e., what perceptions and rationales lie behind their dispositions and strategies *vis-à-vis* conservation interventions (the 'why' of things). Moreover,

in order to avoid superficial assumptions of communities as homogenous and 'closed' entities, intra-community power relations and patterns of inequality needs to be understood, and relationships to other actors and entities (such as the state and other communities) need to be captured.

Drawing on the above approach, our study set out to explore how community members have responded to a particular forest and wildlife monitoring scheme in Iringa Region in southern Tanzania. The study applied a combination of household questionnaires, in-depth qualitative interviews and focus group interviews in four study villages involved in the monitoring scheme, supplemented with supporting data from other sources beyond the villages. Fieldwork for the study was conducted during 2008-2009. Two of the authors resided in the area during most of this period and regularly visited the villages (sometimes daily), while other members of the research team visited the area for 2-3 week periods to conduct intensive fieldwork.

The questionnaire was conducted with a total of 160 households in the four villages, and focused on providing information on livelihoods, forest use and overall perceptions of and engagement with the participatory monitoring scheme. The questionnaire was tested through pilot interviews, and thereafter administered through enumerators. Selection of respondents was based on stratified sampling using well-being rankings, thereby allowing us to examine differences between wealth groups (Grandin 1988; IIED 1992). In practice this entailed: (1) asking key informants to provide information on core features that were considered indicators of well-being in the villages (e.g. land, livestock, marital status, children in school, etc.), followed by; (2) a ranking exercise in which multiple informants divided each household in the village into different well-being categories, leading to an aggregate score for each household which was then; (3) triangulated with other data from the household survey and personal observation of the interviewee's household condition, etc., This allowed us to stratify households into three well-being groups, namely a 'Poorest', a 'Middle' and a 'Wealthy' group (our terms).

The qualitative interviews were conducted with a total of 39 households, and centred on tracing people's actions and interactions in relation to the participatory monitoring scheme since its initiation, and exploring their rationales and perceptions *vis-a-vis* the monitoring scheme and their actions. This was complemented by focus group interviews with (1) members from each of the different well-being categories; (2) members from different forest user groups; and (3) members of the Village Natural Resource Committees that operated the monitoring system. The qualitative interviews with individuals and focus groups used semi-structured interviewing, combined with ranking and scoring techniques of how people perceived different aspects of the monitoring scheme and forest management more broadly (Kvale 1997). Careful probing was used to bring out controversial aspects. Information on actions/interactions were checked with other interviewees and/or informants. The combination of information on actions and perceptions allowed us to check stated perceptions against actual behaviour. Additional data were obtained from key informants in the villages and archival material (minutes from meetings in Village Natural Resources Committees, monitoring records, etc.).

The study also benefitted from a series of other past and ongoing studies in the area on the local economics and effectiveness of participatory forest management and monitoring (Topp-Jørgensen et al. 2005; Poulsen et al. 2007; Lund 2007b; Lund and Treue 2008; Vyamana et al. 2008; Danielsen et al. 2011; Nielsen and Treue 2012; Nielsen and Lund 2012; Danielsen et al. In press).

LIVELIHOODS AND FOREST MANAGEMENT IN THE STUDY AREA

In the late 1990s, the Tanzanian Government instigated a major reorientation in its approach to forest management, shifting from a centralised, state-led policy towards a greater emphasis on Participatory Forest Management (PFM) (Wily 2001; Blomley et al. 2008; Robinson and Maganga 2009). The new approach was enshrined in the Tanzanian Forest Act of 2002, which provided communities with two different ways of engaging in PFM. The first of these is known as Community Based Forest Management (CBFM) and takes place on village land or privately owned land in communities. Under CBFM, villages (or groups and private entities within villages) may gazette Village Forest Reserves (hereafter referred to as Village Forests), and thereby transfer management authority over these forest resources from the state to the community. This includes the right to collect fees on forest utilisation, and to impose and retain fines on illegal use. The second form of PFM is known as Joint Forest Management (JFM) and takes place on state-owned land. Here communities engage in collaborative forest management agreements with the Government (or other forest owners) and share management responsibilities for State Forest Reserves. This provides communities with certain use rights, but revenue collection opportunities for villages are more limited than under CBFM, and the forest land remains under direct state control and ownership.

Today, some 11% of Tanzania's forest area is managed under either of these PFM arrangements, involving more than 1800 villages across the country (Blomley et al. 2008). Our study focused on four such villages, located in Iringa Region in southern Tanzania (Figure 1).

The communities of Itagutwa and Mfyome are located in Iringa District, in an area characterised by dry Miombo woodlands and with a population of 2,136 and 2,375 respectively. The communities of Kidabaga and Magome are located in the neighbouring Kilolo District, some 2 hours drive further south in the montane part of the region. They are characterised by wet closed canopy forest, and have a population of 2,240 and 1,671 inhabitants respectively.

The main ethnic group in the four villages are the Hehe, who are primarily engaged in smallholder agriculture centred on subsistence maize production, as well as cash crops including tobacco. The population of the area also includes a number of

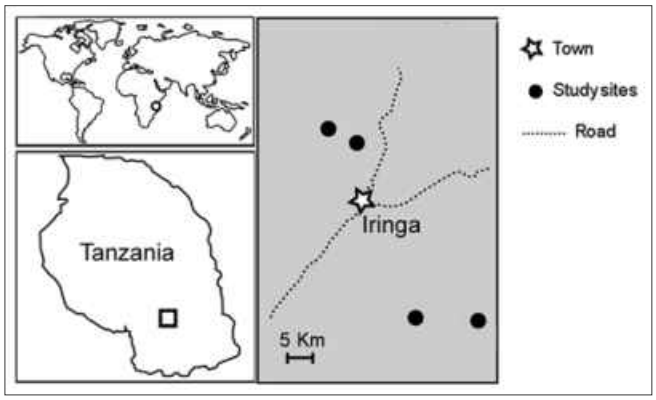

Figure 1
Location of study sites

ethnic minorities, including pastoralists in the woodland areas who have historically migrated to the area from further north.

Historically the forests have played a key role in local livelihoods and continue to do so even today. This is particularly so in the woodland villages of Itagutwa and Mfyome, where crop-farmers rely on forests for firewood, construction materials, charcoal (sold locally and in towns), as well as subsistence foods including wild fruits and vegetables. Pastoralists furthermore graze cattle in the woodland forests. The woodland areas have in recent decades suffered from degradation caused chiefly by wood extraction, including for firewood, charcoal, and small-scale timber harvesting. While this is currently aggravated in some areas by new settlement, there are indications that local management in some areas has contributed to slowing forest degradation and possibly, to reducing utilisation to a sustainable level (Lund and Treue 2008).

In the montane villages of Kidabaga and Magome, many households obtain wood from private woodlots, while wood extraction from natural forests is more limited. However, non-timber forest products such as honey, medicinal plants, plant fibre and particularly bushmeat is of some subsistence importance for poor households in the montane villages (Nielsen 2006). The montane forests constitute an important catchment for the national hydropower supply, and form part of the 'Eastern Arc', a globally important biodiversity hotspot. The montane forest areas were subject to commercial logging in the 1970s and 1980s, but are today *de jure* protected as government/state forest reserves, and illegal logging is not a major concern (Dinesen et al. 2001; Nielsen and Treue 2012).

The four villages studied include examples of both of the two types of PFM permitted within the National Forest Act. In the woodland villages of Itagutwa and Mfyome, the main emphasis is on the CBFM scheme in Village Forests. Here, community members are allowed to extract both wood and non-wood resources from the Village Forests, based on rules and quotas established by the communities and approved by the District Lands, Natural Resources and Environment Office (hereafter referred to as the District Forest Office or DFO). The woodland villages benefit from community taxation of forest use, including charcoal production, small-scale timber extraction, etc. Taxes are then used to cover operational expenses and surplus may be used for small-scale community projects.

The montane villages of Kidabaga and Magome also manage small Village Forests, but these are relatively insignificant and the main emphasis here is on JFM schemes in which communities participate in the management of State Forest Reserves. These reserves have an important strategic role as catchments for hydropower production and for conservation of biodiversity. In accordance with the JFM principles, the state thus formally remains the principal manager in these reserves, and communities are involved mainly as partners who organise local awareness-raising and take part in forest restoration activities and monitoring. Unlike the Village Forests of the woodland villages, wood extraction is illegal in the State Forests, and the ability of communities to generate revenues from forest user fees is limited to a small number of non-timber forest products. As a result, community revenues from the scheme are more limited in the montane villages. Bushmeat hunting is illegal in both woodland and montane forests as this falls under the separate jurisdiction of the Wildlife Department and is not included in the PFM agreements under the Forest Law. Nevertheless, in all of the study villages some households continue to illegally harvest game meat for subsistence or trade[3].

The main organising bodies for forest management in both the woodland and montane communities are Village Natural Resource Committees (VNRCs). These consist of 8-10 members each, democratically elected at Village Assemblies. VNRCs are responsible for decision-making, coordination and administration of all village involvement in forest management. VNRCs formally report to the elected Village Council, and are furthermore obligated to provide relevant information (regular reports including plans, financial statements, monitoring data, etc.) to the state as represented by the DFO. All major management decisions on forest use and taxation in Village Forests must be approved by the DFO to ensure compliance with national law and avoid unsustainable use. Despite the participatory nature of the CBFM and JFM schemes in the four villages, the state formally retains the ultimate authority in overall forest management in the area.

INTERVENTION: THE PARTICIPATORY MONITORING SCHEME

Participatory monitoring in natural resource management constitutes a relatively recent approach to monitoring the status and trends of biodiversity and natural resources in protected areas and elsewhere (Danielsen et al. 2005; Stuart-Hill et al. 2005). Through simple techniques, local community members contribute to, or are responsible for data collection on e.g. wildlife abundance, tree cover, and the extent of natural resource use in a given area.

Data may be collected by dedicated community monitoring patrols who conduct regular transect walks, and be provided by villagers through regular interview sessions in which they provide information on their everyday observations and perceptions of resource use and trends. Based on these data, trends can be interpreted and used in management

decision-making. The extent to which communities are involved in and control the data interpretation and decision-making process may range from an entirely externally led data interpretation and decision-making process to a relatively endogenous process (Danielsen et al. 2009).

The participatory monitoring scheme in the Iringa Region was initiated in 2001 as part of a larger forest and agricultural development programme funded through Danish Government aid. The monitoring scheme was developed with the stated aim of providing information on the status and trends of forest use and forest and wildlife resources for use by communities in daily forest management in the PFM areas. The information would further provide the DFO and Central Government with information on resource trends, and contribute to overall assessment of forest trends and management in the area.

The monitoring scheme was from the outset anchored in the Village Natural Resource Committees, which were to form the main organisational and decision-making body for the scheme at the community level. The scheme was developed through meetings between Government forest staff, international consultants, and community members in the involved villages (including both VNRC members and the broader community). An initial catalogue of methods based on experiences elsewhere was discussed and adapted to fit local conditions. During this process, community representatives requested a particular emphasis on monitoring forest use. Monitoring of biodiversity and specific wildlife species was therefore toned down, although certain indicator species were selected on the basis of VNRC members' recommendations. Following initial testing in two pilot communities, the scheme was rolled out to other communities on a voluntary basis and eventually covered 23 villages with a total population of 54,000 people and 140,000 hectares of forest and woodlands, including the four villages discussed in this article.

The practical monitoring procedure consists of two key activities namely: 1) systematic data collection during patrols (henceforth called 'transect walks') through the forest areas by community monitoring patrols consisting of two to four village scouts, who record signs of resource use, disturbances and selected species (large mammals, birds and tree species); and 2) perception interviews with community members (minimum five households per month) undertaken by VNRC members, asking about household perceptions of forest use and associated changes and trends. The information from these monitoring activities is recorded using standardised forms, and intended to be used by VNRCs to develop and propose specific management actions. Such actions include setting restrictions on particular forms of resource extraction (e.g. disallowing harvesting of certain tree species), changing harvest volumes (amount of firewood to be collected per household), changing prices for resource use (e.g. charcoal licenses) and setting fines for illegal activities.

The monitoring scheme furthermore includes basic procedures to monitor VNRC performance and thereby enhance transparency. This includes regularised records of all VNRC meetings, proposals and activities, as well of financial management transactions (issuing of permits, fees, fines, expenditures, etc.). These records are in principle freely accessible to all community members at any time. VNRCs are required to present collected data on both forest and wildlife trends and financial management at quarterly Village Assemblies. These assemblies also serve as a forum for presenting and debating new regulations on forest use, and for voting on how to spend surplus funds from fees and fines for community use.

Data from the monitoring activities are synthesised in monthly monitoring reports and are in principle submitted along with proposed management interventions to the DFO and other relevant authorities at district level. Significantly, forest management actions proposed by communities require approval from the DFO prior to implementation. Management actions related to wildlife specifically cannot be proposed by communities, being under the separate jurisdiction of the Central Government's Wildlife Division. Hence, while wildlife is monitored by communities under the participatory monitoring scheme, they have no legally backed options for regulating its use or benefitting financially from hunting licenses.

The monitoring scheme was designed to be economically self-sustaining, with operating costs to be financed from the incomes from forest user licenses and fines. Accordingly, no funding was provided for monitoring activities in communities by the donors or government authorities, other than for initial training workshops and technical input in connection to set-up of the scheme. When the larger Danish-funded programme was phased out in 2003, the scheme was left to operate on its own with no external inputs.

MONITORING SUSTAINED: BUT WHY?

In 2005, a field study examined the operational and financial sustainability of the scheme (Topp-Jørgensen et al. 2005). It found that although monitoring activities were carried out less frequently than originally planned in some sites, the scheme was generally continuing to function at the village level[4]. Furthermore, it was found to operate with a high degree of autonomy in the communities, with very little engagement by the DFO.

This picture was largely unchanged when our fieldwork for the current study began in 2007, five years after external technical assistance terminated. The monitoring scheme continued to operate in most of the target villages and VNRC meetings were held on a monthly or bimonthly basis in most villages. The scheme also appeared to sustain relatively broad support among community members. In the four villages covered by our household survey, 86% of all respondents said they felt the monitoring scheme benefitted their household, while 3% were unsure and 11% said it had mainly negative impacts on their household[5] The latter group included respondents whose forest use was illegal according to state law (mainly hunters), or who had been subject to repressive actions by the VNRCs. We return to this issue below.

But while the continued operation of the monitoring system thus suggested a generally positive situation from the initiator's point of view, it also raised questions. The fact that the monitoring scheme has continued in operation without the need for external financial or technical support, and the fact that it maintains a relatively broad support among villagers suggests that the scheme contains significant incentives for communities. But what are these incentives?

In terms of immediate financial benefits, the monitoring scheme forms an important part of the overall PFM system operating in the villages, and thereby contributes to the generation of community revenues from taxation of commercial forest use under PFM. However, for most community members these revenues are of limited significance. One study showed an average annual revenue of USD 604 among the 15 woodland villages involved in the PFM scheme (Topp-Jørgensen et al. 2005). A subsequent study found that the majority of these revenues were used to cover operational and administrative costs associated with the management and monitoring of the Village Forest Reserves (accounting for 69% of expenses), including salaries and allowances for VNRC members and monitoring patrols (Lund 2007b). A much lesser share, accounting for 21% of expenses, were used for community development activities implemented by communities themselves, such as support to school construction, dispensaries and water pipes[6].

In the montane villages, revenues are even smaller. Because the montane villages are engaged in management of State Forest Reserves from which wood extraction is illegal, the most profitable sources of PFM revenues such as charcoal production and commercial firewood collection are unavailable. A study of revenues in the montane PFM villages found an average annual revenue of USD 403 per village. Here, just 12% of revenues have been allocated to community projects. The remainder is insufficient to cover management and monitoring expenses, and monitoring patrols in the montane villages therefore mainly work as volunteers without compensation.

The limited revenues from the scheme were also reflected in our household survey, where only 27% of all respondents said they had benefitted from the community development projects funded by PFM revenues. Despite this, the monitoring scheme has continued to operate in both the woodland and montane villages, and as mentioned above 86% of community members responded that they were positive towards the scheme during our household survey.

This suggested that immediate financial revenues and community projects were not the only perceived benefits from the monitoring scheme. Indeed, when asked directly to name the benefits of the monitoring system, all of the respondents that were favourable to the system mentioned protection against encroachment on forest resources as the main benefit from the scheme. This was also borne out in the qualitative interviews with individuals and focus groups in the villages. During these interviews, community members recognised the value of the community projects, especially when they supported longer-term livelihood strategies. However, they placed even greater emphasis on how the monitoring scheme was a way of supporting individual and collective access to and control over forest resources, thereby ensuring long-term access to forest products and services. Indeed, during ranking exercises, focus groups and most individuals consistently ranked improved community control over forest resources as the most significant benefit of the monitoring scheme.

In the following section, we elaborate on this, discussing how the monitoring scheme is perceived and used by community members as a means of asserting and demarcating rights over forest resources at three levels, *vis-à-vis* other communities, the state, and fellow community members.

MONITORING AS TERRITORIAL DEFENSE

For both the DFO staff and the technical experts involved in the initial development of the monitoring scheme, its main purpose was to provide information on the status and trends of forest resources. This was also emphasised during training and establishment of the scheme. Apart from this, the village monitoring staff has the mandate to apprehend illegal forest users whom they encountered during their monitoring transect walks (i.e., users that have no permits or are otherwise breaking the rules set down by the VNRC). For the DFO staff and technical experts, this was merely an add-on benefit from the monitoring process, to which they did not afford much attention during the original design and training. Nevertheless, in all of the villages studied, the policing role of the monitoring staff has become a key aspect of their work, and is afforded much emphasis by both VNRC members and the majority of other community members interviewed, regardless of wealth status. In the household survey, 56% of all respondents stated that making arrests and reporting on illegal activities was the most important task of the village monitoring staff. Just 35% of the surveyed households found that monitoring of forest and wildlife trends was the most important task, despite this being the original focus of the scheme[7].

In daily practice, the monitoring staff is encouraged by VNRC members to abandon monitoring activities whenever they encounter illegal users, in order to apprehend and return them to the village, where fines are issued. If the illegal users prove hostile or escape, larger search parties involving other community members may be organised in order to locate the offenders. Such search parties are not a required part of either the monitoring scheme specifically, or of the larger community forest management framework. They are also associated with some risk if the arrest turns violent. Despite this, they were usually undertaken with vigour by those involved.

Behind this emphasis on the monitoring scheme as a means of patrolling and policing the community forest lie several rationales. During interviews, VNRC members and some other village members said they found it crucial to enforce the rules and regulations of the community forest in everyday practice, or it would not be respected. They also acknowledged the importance of ensuring that user fee payment and fines were actually paid by forest users, as this provided the basic incomes

through which the entire VNRC and monitoring scheme was financed on a daily basis. However, both VNRC members and other village members expressed a further rationale on which much emphasis was placed, namely that the transect walks served as a way of protecting the Village Forest against forest users from other communities. This had both a practical and a symbolic dimension–in practical terms, the policing helped to physically deter (or apprehend) external forest users, while in more symbolic terms it served as a way of physically demarcating the Village Forest *vis-à-vis* external users.

One illustration of this is the Itagutwa Village Forest. As a result of heavy migration to neighbouring areas, the woodland forests around this village have been under extensive pressure in recent decades, as new settlers seek firewood, timber for charcoal and bushmeat. Past attempts by the head of Itagutwa village to claim the forest as belonging to his village have failed, as neighbouring communities refused to recognise Itagutwa's authority over the forest. However, with the gazettement of the area as Itagutwa's 'Village Forest', the VNRC have been able to refer to a legally sanctioned right, and to engage in formal meetings and negotiations with neighbouring villages and their leaders. The transect walks provide a physical backing to this claim, by physically and symbolically 'marking off' the territory *vis-a-vis* other communities. As one woman from Itagutwa put it; "It shows them that this forest belongs to us". The Itagutwa VNRC have furthermore used the information collected through monitoring as an argument in their negotiations with the neighbouring villages, by claiming that they are the ones who know the forest and its condition best, and that they therefore are its best custodians.

Similar practices took place in other situations and other Village Forests in the area. For instance, in the woodland areas charcoal producers frequently arrive from other locations and stay in the forest while charcoal is produced, after which it is sold in Iringa town or further afield. Although these are subject to community taxation under the Village Forest Scheme, some external charcoal producers seek to evade these fees, or produce beyond their permits. In this context the monitoring is perceived by community members as a means of keeping external charcoal producers 'in check', partly by keeping track of signs of illegal production, but especially by apprehending and deterring illegal producers. A similar rationale was employed in connection to firewood collection, where many women said the monitoring was a means of avoiding competition from women in other villages—thereby also saving them time as firewood was more readily and exclusively available.

In some areas, even community members who themselves were involved in illegal activities used the monitoring as a strategic measure against external users. In the village of Mfyome, for instance, some local hunters recounted how they actually supported the monitoring scheme, although they themselves were at risk of being apprehended for their illegal hunting. As local residents in the village they were able to work out the routine of the monitoring patrols and thereby avoid them, whereas hunters from other villages did not have this information and were now more reluctant to hunt in the forest. They also explained that they considered the monitoring scheme a protection against illegal tree cutting, thereby helping to conserve habitat and hence ensuring a sustained wildlife population[8].

The monitoring system was thus employed by community members in the study villages as a means of territorial defence against forest and wildlife users from other communities. In this respect there are parallels to the communities described by Wily and Dewees (2001) in northern Tanzania, who organised themselves against encroachment of their forest resources, thereby providing some of the initial inspiration for the introduction of participatory forest management in Tanzania.

Significantly, the 'territorial' dimension of the monitoring system in our study area was not part of the initial concept and design, which focused on generating data and information on forest and wildlife trends. Yet through the actual practices of community members, it evolved into a central aspect of the everyday implementation of the monitoring system, thereby extending the scope of the system. For the District Forest Officers who had supported introduction of the monitoring system, this development was in some respects positive. Not only did it suggest a willingness of community members to take on an active role in protecting their forest resources against encroachment, it also provided a convenient means of ensuring regular patrolling of forests without the need to draw on the limited resources of government forestry staff.

Nevertheless, by expanding the scope of the monitoring system, community members were also removing certain aspects of the system beyond the reach of the forest officers and thereby the state. This is partly illustrated by the example described above, whereby some local hunters relied on the monitoring system to fend off hunters from other communities, while still continuing their own hunting despite this being illegal under state law. Yet while such behaviour is perhaps best explained as *ad hoc* opportunism, other practices in the monitoring system suggested a more direct and deliberate effort to move beyond the control of the state. This is discussed in the following section.

SEEKING BEYOND STATE AUTHORITY

The monthly monitoring reports to be delivered by VNRCs to the DFO and other Government authorities served two principle aims at the district level. Firstly, they provided data on the status and trends of natural resources to the DFO in a low-cost manner. And secondly, they contained the proposed management actions made by each village, for approval by the DFO. Ideally, this procedure provided a means for the external regulating agencies to supervise and monitor forest resource trends in the region, as well as to ensure that the management proposal made by VNRCs were in compliance with the overall forest law.

However, exactly because they are meant to contain information on the status and trends of forest resources, the reports are in principle also a very tangible documentation of the success or failure of communities as managers of the forest *vis-à-vis* the state. For community members, having to submit

the monitoring reports to the DFO therefore signified not only a bureaucratic burden, but also an attempt by government agencies to maintain control over the forest resources. During individual and focus group interviews, VNRC members and other villagers questioned the intentions behind the DFO's requirement for the monitoring information, perceiving it as a lack of faith in their forest management capabilities. Some community members even considered the data gathering as being purely for the benefit of the DFO, and preferred that the community monitoring staff should focus exclusively on enforcement. The need for DFO approval of management proposals was also brought into question. VNRC members made frequent reference to the delays in obtaining DFO approvals of management proposals (see also Topp-Jørgensen et al. 2005), and described the reporting to the DFO as an unnecessary burden or a direct attempt by the DFO to retain authority in Village Forests.

Behind these perceptions lies a history of state control over forest resources in Tanzania since colonial times, and a tradition for protectionist and top-down management of forest and wildlife resources. Colonial and post-colonial forest management policies have traditionally emphasised revenue generation for the state, and included strong elements of social engineering through e.g. relocation of forest users and efforts to curb local forest use practices (Sunseri 2009). The protectionist approaches employed in the establishment of protected areas and biodiversity conservation measures in many forest areas during the 1980s and 1990s have further compounded community members' scepticism towards government forestry staff (Wily 2001; Brockington 2002; Goldman 2003; Igoe 2004; Nelson et al. 2007; Sunseri 2009). Moreover, while PFM is now becoming well-engrained as a key approach in the DFO, some government extension officers remain sceptical towards both PFM in general and participatory monitoring specifically. Many local forest users therefore remain wary of engaging in close cooperation with DFO staff.

At the same time, however, community members are well aware of the continued ultimate authority of the DFO and other state agencies in forest resource management, including the DFO's ability to revoke management proposals. This poses the DFO as a powerful authority whom communities cannot choose to merely ignore. In extension of this, part of the legitimacy and clout of VNRCs and their management recommendations stem precisely from the fact that they have been approved by a powerful authority such as the DFO. On the one hand, communities thus wish to become as autonomous in their forest management as possible, while on the other hand they are at least partly dependent on the DFO's support to PFM and the legitimacy and opportunities that this provides. As one VNRC member stated; "We have to work with them […] but our goal is to be free of them".

The efforts of communities to navigate this two-sided relationship with the state in forest management are evident in the way the monitoring scheme has been internalised locally. The majority of VNRCs duly deliver the required monthly reports, including both monitoring information and management proposals (Topp-Jørgensen et al. 2005). And yet at the same time, VNRCs have actively sought to gain greater autonomy in the monitoring and associated decision-making by seeking to move the everyday monitoring practices beyond the reach of the DFO. This can be seen both in the collection of data, in the analysis of these data and in the subsequent management actions taken by the VNRCs.

In terms of data collection, some VNRCs have devised additional data collection methods on their own account. For instance, in one village women are allowed to collect firewood in certain areas on the condition that they report back to the VNRC on any unusual wildlife and forest use observed in the area. In another village, a similar scheme reduces license fees for grazing in the forest, provided that cattle owners regularly report to the VNRC on the condition of forest grazing areas and the extent of illegal use. The DFO has not been informed of the introduction of these practices, and the information generated is typically not included in the formal reporting formats and reports prepared by the VNRC to the DFO. During interviews, VNRC members explained that since the monitoring scheme belonged to the community, they did not wish to provide information to the DFO beyond what was strictly required.

A similar approach was evident in terms of data analysis. In principle, VNRCs are required to compare monitoring data over time and reflect explicitly on trends and possible causes in the monthly monitoring reports. Yet most monthly reports from the villages provide only raw data, and are either very sparse on analytical reflections or omit them entirely. Closer investigation showed that VNRCs did in fact reflect on trends and causes, but chose to do so in their own way. Rather than conducting a numerical analysis of the data in the formal monitoring protocols, VNRC members orally debate the condition and trends of the forest at regular intervals. Significantly, individual perceptions were not accepted off-hand, but were instead subjected to debate among VNRC members and with a strong focus on practically generated experiences among all involved. In this process, the normally inferior status of monitoring staff in the VNRCs was inverted as their recounts and experiences from monitoring walks was given much weight. Likewise, those VNRC members who conducted 'perception interviews' with other community members played an important role in these discussions. Apart from this, several VNRCs also frequently carry out monthly, quarterly or bi-annual supervisory monitoring transect walks in addition to those required by the formal procedures. These typically consist of the entire VNRC and in some cases also members of other village committees. The intention is to validate the perceptions and information provided by the patrol guards, and to allow all VNRC members (and other village institutions where these are involved) to see and assess particular issues and areas for themselves.

This emphasis on orally communicated, experience-based data analysis reflects the traditional local epistemology of the area, in which knowledge and observations of forest and wildlife are debated and passed on orally. As such, it differs from the focus on written records and numerical data analysis

that is inherent in the monitoring scheme as initially designed. VNRC members were well aware of this difference, but deliberately selected their own way of conducting analysis. During interviews they expressed concerns that other types of analysis would leave them at the mercy of the DFO and other 'outsiders', who were more proficient in scientific data analysis than themselves. This was seen as a potential opportunity for data manipulation by the DFO, with no options for VNRCs to control the analysis or pose counter-arguments. Retaining the analytical process locally and away from the DFO was thus seen as a means of reducing the risk of external manipulation and interference by the state in the monitoring process.

A third and final aspect of the way in which communities have attempted to remove the monitoring process from external control relates to the decision-making into which the monitoring scheme feeds. Most major management actions prepared by the VNRCs are duly proposed in the monthly reports to the DFO as required (although as mentioned earlier, the analytical rationale behind these proposals is usually not provided). As previously discussed, such state approval is to some extent necessary in order to obtain the power of state backing that helps VNRCs establish authority, impose controversial rules, demand fees, etc.

However, during the everyday implementation and enforcement of these management actions VNRCs act very much at their own discretion, and in so doing frequently adapt formally approved rules and principles to the situation at hand. In one village, the monitoring patrols deliberately 'overlooked' particularly poor households that were engaged in illegal hunting and honey collection, while other better-off households were apprehended and fined. Rather than a reflection of personal favours, this was based on the notion that the poorest had a hard enough time as it was, as well as an assessment that any efforts to punish the weakest only risked bringing the VNRC into disfavour in the community. In another village, VNRC members were instructed by the DFO to pay particular attention to a certain area of forest, but chose instead to focus the monitoring on another area that they considered more critical in terms of securing Village Forest resources. When the local forest officer became aware of this he sought at first to oppose the VNRCs decision, but eventually gave up on the grounds that it would be impossible for him to check on a regular basis anyway.

These attempts to reshape the monitoring scheme can be seen as part of a broader effort by communities to seek greater autonomy in forest management *vis-à-vis* the state. Such discrete resistance to state authority in forest management is not unknown in Tanzania. Sunseri (2009) describes how some communities in colonial Tanzania sought to counter state appropriation of forest resources through various forms of everyday resistance, such as moving boundary markers and dubbing forest plots as 'sacred' as an argument for retaining local control of them (see also Mulwafu 2011).

Significantly, however, community members in our study villages do not seek to entirely subvert the monitoring system, but rather to appropriate and adapt it to their own advantage. This takes place through a pragmatic and discrete tweaking of the knowledge production and decision-making process of the monitoring system, which does not openly counter or 'anger' the state. This allows VNRCs to retain the monitoring system, and to draw on state backing while at the same time seeking greater independence from it. The benefits of this can be seen partly in the ability to secure territorial claims *vis-a-vis* other communities as described above. In addition, both the monitoring system and the associated state backing provide significant benefits to VNRC members internally within communities, as will be seen from the following.

MONITORING AS LEVERAGE FOR 'CONSERVATION ELITES'

We have described above how communities apply the participatory monitoring scheme as a means of seeking greater control over forest resources in relation to other communities and the state. But to what extent does this also apply between different groups within individual communities? The original guidelines for the participatory monitoring scheme were developed by external experts, based on consultations with local communities. The guidelines emphasised the need for an inclusive process involving a broad cross-section of community members, including representation of women and minority groups.

The VNRCs studied had an average gender ratio among members of 57% men and 43% women. Some women in the VNRCs said during interviews that they were reluctant to speak freely during VNRC meetings as it was not common for women to speak up in public forums, or that they felt intimated when in the presence of men with a high social status. This was also our own observation from participating in VNRC meetings.

In terms of well-being status, 16% of VNRC members were ranked in the wealthiest group, while 70% ranked in the middle group, and 14% in the poorest group. This was disproportionate to the general wealth distribution in the villages, with especially the middle group being over-represented, while the poorest group was significantly under-represented[9]. VNRC members were also better educated than the average village household. Members had typically attended 5-7 years in school, and no members had less than 3 years of schooling. However, 19% of community members in our broader household survey had not attended school at all. These were principally from the poorest strata. During qualitative interviews, members with no schooling typically said that this greatly reduced one's options for becoming member of the VNRCs (or any other community organisation), since people would not vote for unschooled candidates.

It should be noted that the VNRCs tended to show better gender ratios and had more members from the lower socio-economic segments than the Village Development Committees and other community level committees. Nevertheless, the tendency towards over-representation of the middle and better-off segments of the village, as well as the

better-educated households members, was notable (see also Lund 2007b; Vyamana et al. 2008).

VNRC membership provides a number of individual benefits. Apart from basic allowances for participating in meetings and other similar activities, it also provides access to strategically important social and economic resources and 'gate-keeping' functions. Nielsen and Lund (2011) discuss examples of embezzlement and misuse of funds among leading VNRC members in some villages, and how the involved individuals have an interest in sustaining their source of income by making the VNRCs appear active through monitoring and other activities.

In addition to such rent-seeking benefits, we found that VNRCs also provide opportunities for local political leverage. Membership of a village organisation typically commands a degree of respect from other community members, and can help develop or consolidate a member's reputation as being experienced in community organisation matters. Most leading VNRC members thus straddled several village organisations. VNRC membership furthermore expands the social network of its members, who get to meet VNRC members from other villages, and take on a role of mediators between the community and government agencies.

The emerging significance of VNRCs as an opportunity for political leverage was well illustrated in one of the study villages, where the VNRC has become a platform for general political manifestation by its leading members, in direct competition with the Village Council. Members of the council in this village have accused the VNRC of seeking to unduly expand its authority into general village development, through its donation of funds to micro-development activities. VNRC members have countered by indirectly questioning the integrity and legitimacy of village council members, including informal allegations that some of these are involved in illegal charcoal production in the area. While not the cause of the conflict as such, the monitoring scheme has become a discursive reference point for both parties. Referring to the monitoring patrols and their emphasis on enforcement, village council members have criticised the VNRC for acting 'like policemen' against the interests of the broader community. Meanwhile, VNRC members refer to their monitoring information as the basis for their allegations against the village council. Such conflicts reflect how the VNRCs and the monitoring system is drawn into broader political conflicts between competing village factions.

The central role of VNRCs in PFM also provides its members with significant say in the management of a key productive resource in the area. This includes the ability partially to control and impose restrictions on other community members' forest use. We therefore examined whether VNRC members themselves represented particular types of forest users by looking at their own main uses of the forest. Of the 28 VNRC members in the four villages, 23 were farmers engaged in crop-production, whose forest use centred on collection of firewood, with supplementary collection of vegetables, fruits and honey, and in some cases grazing of livestock. Of the remaining five members, two were restaurant/shop owners, two had their main income from charcoal production and pit sawing, and one was a pastoralist. Active hunters were not represented in VNRCs at all, as this activity is illegal, although some monitoring staff are former hunters.

The fact that crop-producing farmers are predominant in VNRCs compares well with their relative majority in the villages. Pastoralists are however underrepresented by just a single representative across the two woodland villages, and the fact that hunting is illegal means that active hunters are marginalised in terms of formal VNRC representation and decision-making. In several cases the VNRCs have shown a distinct tendency to disregard or even oppose the interest of minority groups in forest management. For example, in the village of Mfyome the VNRC has proposed that an entire sub-village is resettled. Households in the sub-village are particularly heavily dependent on forest resources, including illegal hunting, and are viewed by some VNRC members as being 'primitive' and 'destructive' to the forest. In making these allegations, the VNRC has referred to information obtained through the monitoring scheme on the community's forest use. The sub-village has so far resisted the proposal by threatening to seek independent administrative status, as well as soliciting support from local and external patrons and authorities outside the forest sector. However the issue remains unresolved, and the VNRC has opposed the construction of a new school in the area (see also Lund and Treue 2008).

Similar hard-line approaches have been taken by other VNRCs. In the montane villages, VNRCs have employed threats of excessive punishment in an attempt to establish authority, such as spreading the incorrect rumour that illegal forest users risk up to 30 years imprisonment if caught during monitoring patrols (see also Nielsen and Treue 2012). In the woodland areas where farmers and pastoralists frequently compete for access to resources, some VNRC members have called for heavy restrictions on pastoralists' grazing in Village Forests, claiming that they are 'invading' community forests. As support for these claims, VNRC members have referred to monitoring information showing declines in forest resources, even if this information does not specifically link the observed decline to the forest use of pastoralists. In some instances such requests have been dismissed, while in other cases they have led VNRCs to disallow grazing of pastoralists' cattle in some areas, with little or no dialogue with the pastoralists themselves.

Such instances illustrate how the monitoring scheme is applied by some VNRCs to help legitimise a rather autocratic conservation approach that is somewhat different from the inclusive and participatory principles initially envisaged. These tendencies are also evident in other aspects of the monitoring process. While the broader community can provide input to data collection and take part in debates at village assemblies, the actual analysis of data and associated decision-making was conducted almost exclusively by VNRC members. Major decisions proposed by the VNRC are usually presented at village assemblies, but community members are usually not provided with the information on which the analysis and management decisions are based, and

debates tend to be dominated by leading village members as per custom. Moreover, households living far from the village centre (which often includes the poorest and most intensive forest users) frequently do not attend Village Assemblies. This echoes what appears to be a general tendency of asymmetric distribution of knowledge and information about participatory forest management in communities in Tanzania (Robinson and Maganga 2009).

During our qualitative interviews, some community members pointed out that VNRC members benefitted from monopolising monitoring data, since it provided them with knowledge of other community members' resource use that could be used strategically for personal gain. In the montane villages, monitoring patrols have in a few cases demanded a bribe from illegal forest users, in return for not reporting them. We were not able to establish other examples of this, and it is questionable whether such practices are widespread. However, as one community member pointed out, the very risk of it happening meant that one had to treat VNRC members with a certain respect.

The responses of community members to these autocratic tendencies in VNRCs vary.

In cases were specific forest user groups have had use rights curtailed without prior consultation and negotiation, they have usually responded negatively, and also tended to express the most critical views of the VNRCs and the monitoring scheme during interviews (see also Nielsen and Meilby In prep.). The majority of respondents, however, continued to support the notion of the VNRCs and the monitoring scheme, even if they recognised and disagreed with the hard-line approach. During our interviews, they would typically explain that the advantages of community management and monitoring outweighed whatever mistakes the VNRCs made, and that the most important issue was to ensure and maintain community access to the forest. In extension of this, some respondents stated that it was better to deal with 'difficult' VNRC members of their own kind, than having to deal with government agencies.

Such reasoning suggests a pragmatic approach, whereby the advantages of securing community control of forest resources are given primacy, even if this involves dealing with the authoritarian tendencies of those who represent the interests of the community *vis-à-vis* other communities and the state. It further reflects that VNRC members are first and foremost local elites and thereby need to maintain a certain degree of local legitimacy and responsiveness to other community members. One example of this is when VNRC members turn a blind eye on the illegal forest use activities of the poorest households, as mentioned earlier. The need to maintain a degree of legitimacy towards the wider community thus creates certain limits on how far one can go in exploiting the benefits of VNRC membership. Nevertheless, there is some irony in noting how the autocratic approaches of VNRCs echo the state-led authoritarian approaches that participatory conservation schemes claim to be a reaction against.

DISCUSSION AND CONCLUSION

As mentioned at the outset of this article, academic studies of participatory schemes have often pointed out how such approaches can easily become a means of co-opting local communities into taking on external agendas (Kothari 2001). From such a perspective, one might have expected the participatory monitoring scheme in Iringa to develop into an externally controlled instrument of co-option *á la* Foucault's "Panopticon", whereby communities monitor and discipline their own resource use for the benefit of the state. In extension of this, one might have predicted a short life-span for the scheme, as communities turned their backs on yet another conservation initiative driven by outsiders' agendas.

Instead, our findings show how communities in the area have actively engaged the monitoring scheme as part of their efforts to collectively and individually assert control over forest resources *vis-à-vis* the state, other communities and other community members.

This suggests that we need a more nuanced understanding of local actor responses to protected area management (Sodikoff 2007; Ravnborg 2009). The case discussed here thus highlights three issues that require increased attention in analysis and practice, namely; 1) how we understand the actions, interests and incentives of local actors in participatory conservation; 2) how issues of elite capture may be understood and addressed; and 3) how inclusive and participatory conservation measures should be approached and implemented.

Expanding the notions of benefits and incentives

Research and practice on participatory approaches to protected area management and associated resources have often focused on the importance of providing direct financial incentives for local communities, either as compensation for lost resource access or as various forms of Payment for Environmental Services (Frost and Bond 2008). While such benefits will often be highly significant to community members, the case discussed here suggests a need to also recognise the importance attached by community members to other more indirect social and political benefits. In Iringa, this is illustrated by the ways in which a participatory monitoring system comes to provide both individuals and communities with a means to seek greater territorial control over forest resources *vis-à-vis* the state and other actors.

This should not be taken as a suggestion that economic benefits are somehow of lesser significance. On the contrary, the social and symbolic benefits sought by households are typically a means of securing longer-term control and rights over important productive resources and thereby economic capital (Bebbington 2000). What is important is thus to appreciate the composite and multi-layered nature of community members' incentives for engaging in participatory conservation interventions. Rather than thinking solely in terms of short-term financial benefits, local actors may also or instead be driven by more long-term and indirect incentives such as

ensuring food security and enhancing territorial control over resources (Wily 2001; Wollenberg et al. 2001; Langton et al. 2005; Hvalkof 2008).

Policy makers and implementing authorities need to take this into account when developing conservation and development interventions. This is important in relation to ongoing community-based forest and wildlife management schemes in Africa and elsewhere. It is also significant in the development of global incentives-based schemes such as those currently under development in relation to REDD+ (Zahabu and Jambiya 2007; Burgess et al. 2010; Danielsen et al. 2011).

Addressing the issue of local 'conservation elites'

There has recently been increasing reference to the issue of 'elite capture' in community based approaches within conservation and more generally (Tai 2007; Labonne and Chasse 2009; Lund and Saito-Jensen 2013). Nevertheless, the actual nature of such elites and the ways in which other community members perceive and relate to them remains poorly understood in the context of conservation.

The development of the VNRCs and their monitoring scheme in Iringa indicates how participatory conservation interventions may contribute to the development of what could be termed 'conservation elites' within communities. Participatory monitoring schemes do not necessarily lead to such situations, but where systems of information collection and management are monopolised and made exclusive by community elites, they risk becoming powerful platforms for autocratic decision-making and control over key productive resources.

However, our study also suggests that it is important to avoid making simplistic statements about the nature of such 'elite capture' in participatory conservation. While some VNRCs in Iringa were indeed dominated by existing elites, others served as platforms for other community members to challenge the authority of existing elites and their institutional platforms. Moreover, part of the status of community conservation organisations comes exactly from their ability to represent the community in forest management, and as discussed above a certain degree of legitimacy must therefore be maintained in this respect. Community conservation organisations such as the VNRCs thus operate in the complex political terrain typical of many local institutions in natural resource management (Lund 2007a). In so doing, their members may seek to satisfy both collective interests of territorial claim over forest resources while at the same time profiting individually, thus displaying a mix of individual and collective interests that defies simplistic efforts at classifying their motives as either 'good' or 'bad'.

This does not, of course, imply that the interests of the poorest and marginalised groups are automatically represented by local conservation elites. Greater attention is thus needed to the particular interests of such groups in devolved and participatory protected areas management[10]. Significantly, this must build on and enhance the strategies already applied by the poor in seeking to influence protected area management (or their prioritisation of other activities considered more important), rather than imposing preconceived modalities for 'making' the poorest participate.

From blueprint participation to political negotiation

There is nothing new about the use of local knowledge production as a means of social and political empowerment. On the contrary, this is a basic notion in much participation thinking, and is evident in numerous participatory approaches and technologies, including in natural resource management (Brosius et al. 2005; Rijsoort and Jinfeng 2005; Fortmann 2008).

What is interesting to note in the case of Iringa, however, is how such participatory technologies themselves are tweaked, innovated and re-interpreted in daily practice, and how they are thereby brought beyond the reach of both the government authorities and the conservation and development experts who initiated the scheme. The actions of local community members in this respect can be seen as a means of avoiding the co-optive aspects of participation, whereby actors are 'participated' to become self-disciplining and self-surveilling subjects.

Such efforts clearly have their limits, and it would be wrong to suggest that community members are able to reshape the monitoring scheme and its outcomes entirely at will. At the end of the day, the state retains the ultimate power to cancel the monitoring scheme and revoke the status of Village Forests. It should also be noted that many Village Forests are of relatively lesser economic value to the Tanzanian government than the state controlled forests and national parks. For instance, in areas where wildlife revenues are high, state imposition and clamp-down has tended to be more vigorous than in the participatory forest schemes discussed here (Brockington 2002; Goldman 2003, 2011; Nelson et al. 2007, Meroka and Haller 2008). In other words, the available space for communities to reshape conservation interventions–whether participatory or not–is always to some extent dependent on the surrounding political and economic interests and structures (Ribot et al. 2008).

Community members are of course fully aware of this, as evident in the two-pronged strategy of the communities discussed here, in which they seek to maintain good ties with DFO officers while at the same time imposing their own discrete changes to the monitoring system. In so doing, they illustrate not only how communities may exploit the limited reach of a state in the everyday implementation of conservation efforts, but also the extent to which community members consider it worthwhile to make the effort in the first place, despite the challenges and risks involved.

From a normative empowerment perspective, this is positive in several ways. For one thing, it displays in abundance the much sought after local 'ownership' in conservation and development interventions. It furthermore shows how apparently mundane mechanisms such as a monitoring scheme can be exploited by communities as supplementary platforms for pursuing and consolidating community forest rights.

These are outcomes which go some way beyond the original community benefits envisaged by the external initiators of the monitoring scheme.

Significantly, the lessons from Iringa are not only relevant for the more instrumentalist schemes for community participation in conservation, but also for co-management schemes where communities are engaged as actual 'partners'. In this respect, it seems particularly critical to avoid simplistic notions of communities as unified parties whose strategies and interests *vis-à-vis* conservation can be predetermined and aligned with state interests in once-and-for-all management plans and 'joint visions'. Instead, a more flexible approach is needed which provides space for communities to appropriate and innovate conservation interventions within co-management arrangements. As such, our findings from Iringa echo the calls for adaptive management approaches in conservation (Berkes 2003, Colfer 2005, Stringer et al. 2006, Williams 2011). This includes accepting the uncertainty of outcomes, and allowing for greater flexibility and plurality in the development and implementation of management practices.

This does not imply that communities should not be held accountable or responsible for their actions in conservation terms. Protected areas typically contain biological and ecosystem values of wider regional, national and global significance that need to be accommodated. In many cases, such values can be managed fully and sustainably by local communities. In other situations, circumstances may require that management responsibilities and decision-making needs to be shared by different local and non-local stakeholders, with mutual obligations and responsibilities. Regardless of the necessary arrangements, the key factor is to approach and engage communities as capable political agents in their own right.

ACKNOWLEDGEMENTS

The authors would like to thank our colleagues in the wider Monitoring Matters network for inspiration and dialogue; the Danish Ministry of Foreign Affairs for funding the research programme of which this study formed part; and John F. Massao and Jens Friis Lund for their help. The constructive comments from three anonymous reviewers were also much appreciated.

NOTES

1. See Borrini-Feyerabend (2001) for the evolving role of communities in conservation, and Borrini-Feyerabend et al. (2007) for details on co-management approaches.
2. For this debate, see Topp-Jørgensen et al. (2005); Holck (2008); Danielsen et al. (2010); Danielsen et al. (2011); Nielsen and Lund (2012).
3. This was confirmed in interviews with hunters and other villagers, and witnessed by ourselves. See also Nielsen (2011) and Nielsen and Treue (2012) for details on hunting the montane villages).
4. The study found that transect walks, perception interviews and VNRC meetings to discuss monitoring data were carried out regularly in most of the 23 villages studied, that 80% of the required monthly monitoring reports had been produced and that VNRCs had made 181 proposals for forest management actions based on the monitoring scheme.
5. This did not mean that respondents saw no negative impacts from the monitoring scheme, but that their overall assessment was positive.
6. The remaining expenses were allocated as taxes to the District (5%) or other purposes. See Lund (2007).
7. The remaining households mentioned other purposes such as controlling forest fires, or did not know what to respond.
8. This approach appears to have been particularly prominent among hunters in the woodlands. Hunters in the montane villages tended to have rather more negative attitudes towards the scheme (Nielsen and Meilby In prep).
9. The average distribution across wealth groups for all households in the four villages was 14%, 52% and 34% for wealthy, poor and very poor households respectively.
10. For example, see Child (2006) on governance monitoring in Namibia's community conservancies.

REFERENCES

Agrawal, A. 2005. Environmentality. community, intimate government, and the making of environmental subjects in Kumaon, India. *Current Anthropology* 46(2): 161–190.

Bebbington, A. 2000. Re-encountering development: livelihood transitions and place transformations in the Andes. *Annals of the Association of American Geographers* 90(3): 495–520.

Berkes, F. 2003. Rethinking community-based conservation. *Conservation Biology* 18(3): 621–630.

Blomley, T., K. Pfliegner, J. Isango, E. Zahabu, A. Ahrends, and N. Burgess. 2008. Seeing the wood for the trees: an assessment of the impact of participatory forest management on forest condition in Tanzania. *Oryx* 42(3): 380–391.

Borrini-Feyerabend, G. 2001. Co-management partnerships: a challenging approach for integrated conservation and development programmes. In: *Conservation and development: new insights and lessons learnt* (eds. Agersnap, H. and M. Funder). Copenhagen: Environment and Development Network.

Borrini-Feyerabend, G., M. Pimbert, T. Farvar, and A. Kothari. 2007. *Sharing power: a global guide to collaborative management of natural resources*. London: Earthscan.

Brockington, D. 2002. *Fortress conservation: the preservation of the Mkomazi Game Reserve, Tanzania*. Bloomington: University of Indiana Press.

Brosius, J., A. Tsing, and C. Zerner. (eds.). 2005. *Communities and conservation: histories and politics of community-based natural resource management*. Walnut Creek, CA: AltaMira Press.

Burgess, N., B. Bahane, T. Clairs, F. Danielsen, S. Dalsgaard, M. Funder, et al. 2010. Getting ready for REDD+in Tanzania: a case study of progress and challenges. *Oryx* 44(3): 339-351.

Child, B. 2006. *Developing adaptive performance monitoring for economics and governance of community based natural resource management institutions*. Unpublished manuscript. University of Florida, USA.

Cleaver, F. 2012. *Development through brickolage: rethinking institutions for natural resource management*. London: Routledge.

Colfer, C.J.P. 2005. *The complex forest: communities, uncertainty and adaptive collaborative management*. Bogor: RFF Press and CIFOR.

Cornwall. A. and V. Coelho (eds.). 2007. Spaces for change: the politics of participation in new democratic arenas. London: Zed Books.

Danielsen, F., N. Burgess, and A. Balmford. 2005. Monitoring matters: examining the potential of locally-based approaches. *Biodiversity and Conservation* 14: 2507–2542.

Danielsen, F., N. Burgess, A. Balmford, P.F. Donald, M. Funder, J.P.G. Jones, P. Alviola, et al. 2009. Local participation in natural resource monitoring: a characterization of approaches. *Conservation Biology* 23(1): 31–42.

Danielsen, F., N. Burgess, M. Funder, T. Blomley, J. Brashares, A. Akida, A. Jensen, et al. 2010. Taking stock of nature in species-rich but economically poor areas: an emerging discipline of locally-based

monitoring. In: *Taking stock of nature* (ed. Lawrence, A.). Pp. 88–112. UK: Cambridge University Press.

Danielsen, F., M. Skutsch, N.D. Burgess, P.M. Jensen, H. Andrianandrasana, B. Karky, R. Lewis, et al. 2011. At the heart of REDD: a role for local people in monitoring forests? *Conservation Letters* 4: 158–167.

Danielsen, F., P.M. Jensen, N.D. Burgess, R. Altamirano, P.A. Alviola, H. Andrianandrasana, J.S. Brashares; A. C. Burton, I. Coronado, N. Corpuz, M. Enghoff, J. Fjeldså, M. Funder, S. Holt, H. Hübertz. A.E. Jensen, R. Lewis, J. Massao, M.M. Mendoza, Y. Ngaga, C.B. Pipper, M.K. Poulsen, R.M. Rueda, M.K. Sam, T. Skielboe, M. Sørensen, R. Young. In press. A Multi-Country Assessment of Tropical Resource Monitoring by Local Communities. Bioscience, in press.

Dinesen, L., T. Lehmberg, M.C. Rahner, and J. Fjeldså. 2001. Conservation priorities for the forests of the Udzungwa Mountains, Tanzania. *Biological Conservation* 99: 223–236.

Escobar, A. 1998. Whose knowledge, whose nature? Biodiversity, conservation, and the political ecology of social movements. *Journal of Political Ecology* 5(1): 53-80.

Fortmann, L. (ed.). 2008. *Participatory research in conservation and rural livelihoods: doing science together*. London: Wiley-Blackwell.

Foucault, M. 1995. *Discipline and punish: the birth of the prison*. London: Vintage Books.

Frost, P. and I. Bond. 2008. The CAMPFIRE programme in Zimbabwe: payments for wildlife services. *Ecological Economics* 65(4): 776–787.

Funder, M. 2010. The social shaping of participatory spaces: evidence from community development in southern Thailand. *Journal of Development Studies* (46) 10: 1708–1728.

Giddens, A. 1984. *The constitution of society*. Cambridge: Polity Press.

Goldman, M. 2003. Partitioned nature, privileged knowledge: community-based conservation in Tanzania. *Development and Change* 34(5): 833–862.

Goldman, M. 2011. Strangers in their own land: Maasai and wildlife conservation in northern Tanzania. *Conservation and Society* 9(1): 65–79.

Grandin, B. 1988. *Wealth ranking in smallholder communities: a field manual*. London: Intermediate Technology Development Group.

Holck, M.H. 2008. Participatory forest monitoring: an assessment of the accuracy of simple cost-effective methods. *Biodiversity Conservation* 17: 2023–2036.

Holmes, G. 2007. Protection, politics and protest: understanding resistance to conservation. *Conservation and Society* 5(2): 184–201.

Hvalkof, S. 2006. Progress of the victims: political ecology in the Peruvian Amazon. In: *Reimagining political ecology* (eds. Biersack, A. and J.B. Greenberg). Pp. 195–232. Durham: Duke University Press.

Igoe, J. 2004. *Conservation and globalization: a study of national parks and indigenous communities from East Africa to South Dakota*. Denver, CO: University of Colorado.

International Institute for Environment and Development (IIED). 1992. Applications of wealth ranking. *Participatory Learning and Action* 15: 1–77. London: IIED.

Juul, K. and C. Lund. 2002. *Negotiating property in Africa*. London: Heinemann.

Kvale, S. 1997. *Interviews*. London: Sage Publications.

Kothari, U. 2001. Power, knowledge and social control in rural development. In: *Participation: the new tyranny?* (eds. Cooke, B. and U. Kothari). Pp. 139–152. London: Zed Books.

Labonne, J. and R.S. Chase. 2009. Who is at the wheel when communities drive development? Evidence from the Philippines. *World Development* 37(1): 219–231.

Langton, M., Rhea, Z.M., and L. Plamer. 2005. Community-oriented protected areas for indigenous peoples and local communities. *Journal of Political Ecology* 12: 23–50.

Long, N. 2001. *Development sociology: actor perspectives*. London: Routledge.

Lund, C. 2007a. Twilight institutions: public authority and local politics in Africa. *Development and Change 37*(4): 685–705.

Lund, J.F. 2007b. Is small beautiful? Village level taxation of natural resources in Tanzania. *Public Administration and Development* 27: 307–318.

Lund, J.F. and M. Saito-Jensen 2013. Revisiting the issue of elite capture of participatory initiatives. *World Development* 46(6): 104–112.

Lund, J.F. and T. Treue. 2008. Are we getting there? Evidence of decentralized forest management from the Tanzanian miombo woodlands. *World Development* 36(12): 2780–2800.

McShane, T.O. and M.P. Wells (eds.). 2004. *Getting biodiversity projects to work: towards more effective conservation and development.* New York, NY: Columbia University Press.

Meroka P. and T. Haller. 2008. Government wildlife, unfulfilled promises and business: lessons from participatory conservation in the Selous Game Reserve, Tanzania. In: *People, protected areas and global change* (eds. Galvin M. and T. Haller). Pp. 177–219. Bern: University of Bern.

Mulwafu, W. 2011. *Conservation song: a history of peasant-state relations and the environment in Malawi*. London: White Horse Press.

Nelson, F., R. Nshala, and W.A. Rodgers. 2007. The evolution and reform of Tanzanian wildlife management. *Conservation and Society* 5(2): 232–261.

Nielsen, M.R. 2006. Importance, cause and effect of bushmeat hunting in the Udzungwa Mountains, Tanzania: implications for community based wildlife management. *Biological Conservation* 128: 509–516.

Nielsen, M.R. 2011. Improving the conservation status of the Udzungwa Mountains, Tanzania? The effect of joint forest management on bushmeat hunting in the Kilombero Nature Reserve. *Conservation and Society* 9(2): 106–118.

Nielsen, M.R. and T. Treue. 2012. Hunting for the benefits of joint forest management in the Eastern Afromontane Biodiversity Hotspot: effects on bushmeat hunters and wildlife in the Udzungwa Mountains. *World Development* 40(6): 1224–1239.

Nielsen, M.R. and J.F. Lund. 2012. Seeing white elephants? The production and communication of information in a locally-based monitoring system in Tanzania. *Conservation and Society* 10(1): 1–14.

Nielsen, M.R. and H. Meilby. In prep. Hunting for compliance in joint forest management: the case of bushmeat hunting in the Udzungwa Mountains, Tanzania.

Nuijten, M. 2005. Power in practice: a force field approach to natural resource management. *The Journal of Transdisciplinary Environmental Studies* 4(2): 1–14.

Poulsen, M.K., J. Massao, N. Burgess, and E. Topp-Jørgensen. 2007. Community based monitoring of PFM in Tanzania: initial experiences and lessons learned. *The Arc Journal* 21: 31–33.

Ravnborg, H.M. 2009. Organizing to protect: protecting landscapes and livelihoods in the Nicaraguan hillsides. *Conservation and Society* 6(4): 283–292.

Ribot, J., A. Chatreb, and T. Lankinad. 2008. Institutional choice and recognition in the formation and consolidation of local democracy. *Conservation and Society* 6(1): 1–11.

Rijsoort J.V. and Z. Jinfeng. 2005. Participatory resource monitoring as a means for promoting social change in Yunnan, China. *Biodiversity and Conservation* 14: 2543–2573.

Robinson, E.J.Z. and F. Maganga. 2009. The implications of improved communications for participatory forest management in Tanzania. *African Journal of Ecology* 47 (Suppl. 1): 171–178.

Scott, J.C. 1990. *Domination and the arts of resistance*. New Haven, CT: Yale University Press.

Selfa T. and J. Endter-Wada. 2008. The politics of community-based conservation in natural resource management: a focus for international comparative analysis. *Environment and Planning* (A) 40(4): 948–965.

Sodikoff, R. 2007. An exceptional strike: a micro-history of 'people versus park' in Madagascar. *Journal of Political Ecology* 14: 10–33.

Stringer, L.C., A.J. Dougill, E. Fraser, K. Hubacek, C. Prell, and M.S. Reed. 2006. Unpacking "participation" in the adaptive management of social-ecological systems. *Ecology and Society* 11(2): 39.

Stuart-Hill G., R. Diggle, B. Munali, J. Tagg, and D. Ward. 2005. The event book system: a community-based natural resource monitoring system from Namibia. *Biodiversity and Conservation* 14: 2611–2631.

Sunseri, T. 2009. *Wielding the axe: state forestry and social conflict in Tanzania, 1820-2000*. Athens, OH: Ohio University Press.

Tai, H.S. 2007. Development through conservation: an institutional analysis of indigenous community-based conservation in Taiwan. *World Development* 35: 1186–1203.

Topp-Jørgensen E., M.K. Poulsen, J.F. Lund, and J.F. Massao. 2005. Community-based monitoring of natural resource use and forest quality in montane forests and miombo woodlands of Tanzania. *Biodiversity and Conservation* 14: 2653–2677.

United Nations Framework Convention on Climate Change (UNFCCC). 2010. Decision 2/CP. 15, Copenhagen Accord. UNFCCC, Bonn, Germany. http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf#page=11. Accessed on February 15, 2012.

Vyamana, V.G., A.B. Chonya, F.V. Sasu, F. Rilagonya, F.N. Gwassa, S. Kivamba, I. Mpessa, et al. 2008. Participatory forest management in the Eastern Arc Mountain area of Tanzania: who is benefiting? In: *Governing shared resources: connecting local experience to global challenges*. Conference of the international association for the study of commons. Cheltenham England. July 14–18, 2008.

West, P. 2006. *Conservation is our government now: the politics of ecology in Papua New Guinea*. Durham, NC: Duke University Press.

Williams, B.K. 2011. Adaptive management of natural resources: framework and issues. *Journal of Environmental Management* 92: 1346–1353.

Wily, L.A. 2001. Forest management and democracy in East and southern Africa: lessons from Tanzania. *IIED Gatekeeper Series* No. SA95.

Wily, L.A. and P.A. Dewees. 2001. From users to custodians: changing relations between people and the state in forest management in Tanzania. World Bank Policy Research Paper No. 2569. Washington, DC: World Bank.

Wollenberg, E., A.A. Nawir, A. Uluk, and H. Pramono. 2001. *Income is not enough: the effect of economic incentives on forest product conservation*. Bogor: Center for International Forest Research.

World Bank. 2008. *Forests sourcebook: practical guidance for sustaining forests in development cooperation*. Washington, DC: World Bank.

Zahabu, E. and G. Jambiya. 2007. Community based forest management and carbon payments: real possibilities for poverty reduction? *The Arc Journal* 21: 25–27.

Received: June 2010; Accepted: July 2012

APPENDIX X

Danielsen, F., Topp-Jørgensen, E., Levermann, N., Løvstrøm, P., Schiøtz, M., Enghoff, M. and Jakobsen, P. 2014.
Counting what counts: using local knowledge to improve Arctic resource management.
Polar Geography 37: 69–91.

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Polar Geography, 2014
Vol. 37, No. 1, 69–91, http://dx.doi.org/10.1080/1088937X.2014.890960

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Counting what counts: using local knowledge to improve Arctic resource management

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(*Received 15 January 2014; accepted 31 January 2014*)

The climate is changing and the people in the Arctic are facing huge challenges. Many rely on natural resources for both subsistence and income. Successful adaptation to climate change and the sustainable use of resources requires observation of the environment. Scientific knowledge of the environment is incomplete and conventional scientific monitoring is logistically difficult. Local fishers and hunters observe the environment all year-round. Their observations and knowledge are, however, not consistently quantified, analyzed, or used for resource management. We present a simple, field-based system for monitoring and managing resources developed specifically to enable Greenlandic fishers and hunters to document trends in living resources and to propose management decisions themselves. This system was designed to build upon existing informal observing methods, and there is interest in the system among rural fishers and hunters. We describe correspondence between community members' perceptions and professional scientists' assessments of the abundance of sea-ice, shipping, fish, mammals, and birds. Community-based documentation can pinpoint particular species and areas that are in need of attention. At the same time, it can help link observed environmental changes to management action. We hope this paper will encourage other stakeholders to develop their own local monitoring systems so as to facilitate adaptive management responses at both local and national levels.

Introduction

The polar regions are experiencing rapid environmental changes (Post *et al.* 2009). Knowledge of these changes is necessary in order to adapt the resource management and livelihood strategies of the Arctic communities (Riedlinger and Berkes 2001).

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There is incomplete scientific knowledge of populations and trends in the Arctic's living resources (Meltofte 2013). Local knowledge abounds (Ferguson *et al.* 1998; Krupnik *et al.* 2010; Weatherhead *et al.* 2010) but, with few exceptions (Russell *et al.* 2013), this is not consistently being quantified or used in broader decision-making (Sejersen 2003; Johnson *et al.* 2014). The declarations from the third to the eighth Ministerial Meetings of the Arctic Council (2002–2013) all emphasize the importance of using 'traditional knowledge' (Berkes *et al.* 2000) to address challenges in Arctic communities.

In response to this, several programs for capturing and sharing local observations have been established (Gofman and Smith 2009; Oskal *et al.* 2009; Gofman 2010; Merkel 2010; Huntington 2011; Larsen *et al.* 2011; Mustonen and Mustonen 2011; Knopp *et al.* 2013; see also arcticcbm.org). The Government of Greenland is contributing to such international efforts and has stipulated legal requirements for involving users in the management of natural resources (Greenland Government 1999). Moreover, the government has piloted the development of a community-based monitoring system (Ministry of Fisheries, Hunting and Agriculture 2014).

Each component of community-based monitoring programs presents a set of challenges (Pulsifer *et al.* 2014). For instance, differences in language and worldview can hinder communication and mutual understanding (Berkes 2012). Access to data management systems may be difficult in remote regions or may not be culturally appropriate in some instances. Interpretation of data requires some degree of judgment which, in turn, may distance the initial observation from its local context in the quest to enable comparisons over time and space. This paper outlines how the Government of Greenland has attempted to tackle these and other challenges in developing a systematic system for community-based monitoring in Greenland.

Historically, hunting and fishing in Greenland have undergone major changes. Speed boats have provided access to areas that previously were inaccessible and modern fishing gear and rifles have improved efficiency (Huntington 2013). Combined with historic population growth and a continued cultural importance of fishing and hunting, there is therefore a need for a well-functioning system for regulating resource use.

We describe the Greenland community-based monitoring system from conception to implementation and discuss the findings from the first three years. First, we explain how the system was developed. Then we present the theoretical framework for the system and how it works at the community level. We assess whether community members enroll in the system or not and whether the community members' findings correspond with those of the professional scientists. Finally, we discuss the incentives for the participants, the extent to which the system is culturally sensitive, and we propose some further developments of the system. The article's structure builds on the study of Danielsen *et al.* (2000). Latin names are provided in Annex S1 (supplementary article) (this and other supplementary materials are available on the journal's website). Nomenclature follows Génsbøl 2004.

Methods for developing the documentation and management system

For many Greenlanders, the word 'monitoring' has strong negative connotations. We therefore call this system a 'documentation and management system.' However, the system was not only renamed to appeal to Greenlanders. The system is profoundly different from conventional monitoring systems, as we describe below.

Development and implementation of this system were carried out over a three-year period, from 2009 to 2012, alongside the capacity building of government staff and community members in local documentation and management of living resources in four communities. Our team comprised six professionals in environmental planning, wildlife management and administration from the Government of Greenland, three Greenlandic local authority staff members from Qaasuitsup Kommunia, a Danish ecologist, and a Danish rural sociologist. The Greenland government staff input, in terms of person-months, was approx. five times the external staff input. Every 6–8 months an advisory group met to supervise the work. This group included scientists and government staff and representatives of the Greenland Fishers and Hunters Association (KNAPK), the Greenland Association of Municipalities (KANUKOKA), the Greenland Institute of Natural Resources (GINR), the Inuit Circumpolar Council (ICC) Aarhus University, Norwegian Institute for Nature Research, and Iceland's Environment and Food Agency.

We searched the literature for community-based approaches to environmental monitoring (e.g. Huntington 1998, 2000; Johannes *et al.* 2000; Folke 2004; Huntington *et al.* 2004; Moller *et al.* 2004) and then assessed current natural resource management practices at field level in the communities involved. National and local authority government staff, representatives of KNAPK, and locally resident government game officers participated in the assessments.

The assessments helped us to identify the methodological concepts of the system. With this palette of concepts, we held meetings with local communities to select the system and adapt it to the local context, in terms of human and natural resources and institutional set-up. The tools were tested and adapted over a 24-month period so that we could identify the methodological issues that had to be solved in order to acknowledge the needs of both local communities and authorities. These methodological issues related mainly to: (1) avoiding overburdening the participants by keeping data collection and data management simple and (2) identifying suitable approaches for translating the results into local authority decision-making. This time-consuming process also meant that the conclusions were acceptable to a broader range of people and it encouraged ownership of the system both locally and in the government administrative system.

Based on the literature and the field assessments, we drafted a manual. This was discussed with representatives of the community members, local authority staff, and the advisory group, and the manual was revised accordingly. Five visits were subsequently made by government staff and a Danish ecologist to the communities to assist and supervise them in field implementation (27 April–5 May 2010; 28 September–6 October 2010; 29 January–7 February 2011; 18–23 June 2011; and 22 September–1 October 2012).

The system was initially established in three communities in Disko Bugt and Uummannaq Fiord: Akunnaaq, Qaarsut, and Ilulissat/Jakobshavn (figure 1). As the system was being established, a fourth community asked to be involved, Kitsissuarsuit/Hunde Ejland. Whereas Kitsissuarsuit, Akunnaaq, and Qaarsut are small settlements with 79, 101, and 196 inhabitants, respectively, Ilulissat has a population of 4546 and is the third largest town in Greenland (2010 figures; Statistics Greenland 2013).

Theoretical framework for participatory documentation of resources in Greenland

The Government of Greenland wants to establish 'adaptive management' (Berkes *et al.* 2000) by ensuring that relevant decisions and actions are taken for the management of living resources. Decisions can be taken at different levels: local community, local (municipal) government authority, and central government (figure 1). Repeated data collection or 'monitoring' is important in order to identify and understand status and trends and thus improve decision-making on resource management (Spellerberg 2005).

Examples of biological questions that monitoring can answer:

- Are populations of animals increasing or decreasing?
- Are animals arriving later or earlier than 'normal'?

Examples of resource management questions that monitoring can answer:

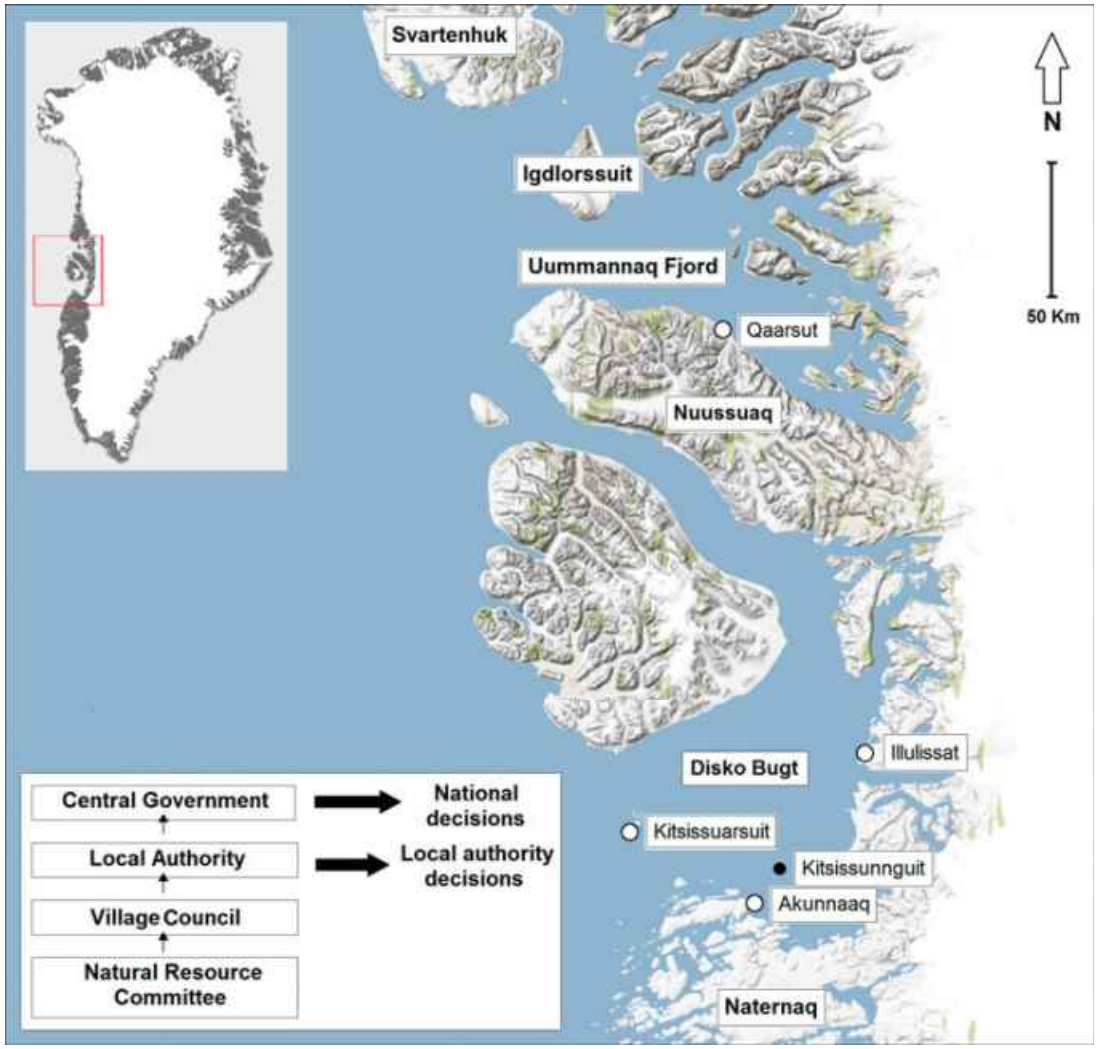

Figure 1. The locations of the areas in Uummannaq Fjord and Disko Bugt, North West Greenland, that are mentioned in the text. Abbreviations: Km, kilometers; N, North. The diagram shows the flow of recommendations (small arrows) between the different institutional levels and the associated decisions on natural resource management (large arrows) that can be taken within the current regulations.

- Is there a need to adjust the management of certain populations or species?
- Are the regulations having the desired effect on stocks?
- Is there a need to investigate some observed changes in more detail?

In other words, monitoring can decide whether management initiatives in the region are effective in addressing human and climate-induced changes in the living resources. When combined with explicit management aims for populations of fish and wildlife, monitoring can help the citizens adapt resource utilization in order to get the most out of the existing resources within sustainable limits.

Existing monitoring activities

In some areas of Greenland, there are local ways in which hunters control access to resources. For example, in accordance with Qaanaaq municipality by-laws, hunting of narwhale is only allowed using traditional hunting methods (Nielsen 2009). Moreover, merely by living in the coastal areas, using the resources and observing their environment, the communities notice changes in the resources. The monitoring system was designed to build upon and strengthen such existing informal community-based observation and management systems.

Aside from this, most monitoring of Greenland's living resources takes place by hunters and fishers reporting their catch to the government and by scientists carrying out monitoring and research-based studies. Since 1993, the government has collected harvest statistics on a national scale (Merkel 2011). These statistics, in principle, include all hunting in Greenland, but also egg collection, gillnet harvest of ringed seals and, since 2002, bycatch of guillemots and eiders.

Available human capacity and financial resources

The availability of human capacity and financial resources has an important bearing on a monitoring system. At the local level, communities in Greenland are usually supported by a service-center that hands out forms and licenses, etc., and one government official for all aspects related to economic development in that community. Typically, this official is responsible for several communities in a wide area. The person frequently has experience of local authority administration or the private sector. Given their workload, they have very little time available to assist in monitoring efforts, and this is not likely to change.

At the central government level, human resources are limited to 10 people responsible for the government's wildlife management, around 10 people for fisheries management, and 9 locally resident government game officers. It is difficult for them to achieve management aims, given the current tasks and priorities. There is, therefore, also limited time for additional tasks related to a community-based monitoring system, e.g. data handling and community feedback.

The GINR has more than 50 employees who conduct research and provide advice to the government on the basis of scientific protocols (GINR 2013). With government and external funding, the institute implements three- or five-year monitoring plans. Local hunters and fishers may assist as paid data collectors following standard scientific protocols.

The financial resources available for monitoring are also limited. GINR monitoring focuses on the stocks of highest socio-economic value and is complemented by

external funding. External funds are particularly needed for those stocks where the harvest is low relative to the cost of surveying, such as polar bear in West and East Greenland and walrus and whales in East Greenland (F. Ugarte *in litt.)*.

Natural resource monitoring has to compete for staff time and funds with other government focus areas such as social welfare, hospitals, and schools. When developing the system, we had to acknowledge these limitations in human capacity and finances.

Approach and methods of the documentation and management system

The objective of the system is to help decision-makers in communities, local authorities, and central government by providing information from the regular collection and interpretation of data on living resources and their utilization. The focus is on *detecting changes* in natural resources and their use as early as possible in order to *guide decision-making* on resource management.

The system's specific objectives are to:

- strengthen documentation of the locals' knowledge of the living resources by utilizing their observational capacity;
- encourage local analysis, interpretation and discussion of changes in the living resources, thereby increasing local capacity and creating an understanding of the need for management interventions;
- make local observations, analysis, and recommendations available to the government;
- enhance the local stakeholders' influence over government decisions on fishing and hunting;
- provide a forum for data-based dialog between local stakeholders and the government.

Who can monitor resources?

Monitoring of the living resources is carried out by natural resource committees (NRCs) in each community. The NRCs consist of 5–12 people who are interested in helping to manage the living resources. They typically come from those families in the community who are significant users of the resources, often including the most experienced fishers and hunters. The participants are often also involved in voluntary work in the local branches of fisher and hunter organizations.

The NRCs are established at village meetings where interested individuals have the opportunity to join the committee. It is the government's intention that the NRC members should represent different age groups and include middle-aged, young, and old. The NRC elects a coordinator who reports to the Village Council. When NRC members are in the field, they gather data on the living resources and their use. These data are summarized, discussed and analyzed at committee meetings, and possible management initiatives are considered (guidelines for facilitating NRC meetings are found in Annex S2).

What are the responsibilities of the NRCs?

At the NRC meetings, the members are responsible for:

- proposing monitoring targets, i.e. selecting living resources and resource uses that the NRC has an interest in and an ability to observe, and proposing to the government that it should keep track of them;
- the NRC members agree on the names and boundaries of each of the sites where they will monitor the selected species and resource uses;
- providing management recommendations and advice to the Village Council and the local authority on the basis of their observations;
- organizing separate census activities for, e.g., caribou, musk ox, fish, and birds, as needed.

How are data collected and used?

The two methods used for data collection are: (1) patrol records kept by community members and (2) community focus group discussions on the status of the natural resources and resource use (Danielsen *et al.* 2014). Patrol records entail filling out sheets on a standard calendar (analog, with one page per day) with the community members' own observations and records of key species and resource uses immediately after hunting, fishing and other trips to the field (Danielsen *et al.* 2005). Survey effort is localized and varies between trips, and different habitats are sampled unrepresentatively. Measures built into the system to reduce potential biases are described in Annex S3.

The data collected by NRC members are interpreted at their meetings. The proposed management decisions, with supporting data, are used by the community, the local government authority, and the central government when taking decisions about the management of living resources (figure 1). Some of the information will make the Village Council, local authorities, and government aware of perceived local management needs and conditions that need further exploration by the government, e.g. significant changes in species distribution and abundance.

What are the steps to establishing and implementing the system?

There are five steps to establishing and implementing the system in each community:

Step 1. Identifying a natural resource committee

The Village Council in each community chooses the members of an NRC on the advice of local fishers' and hunters' organizations, the local authority staff, and local game officers.

Step 2. Making observations

After each trip to the field, the NRC members enter data on observations and catches on a personal calendar, specifying the resource or taxon, the quantity, time, and place. For example, Karl Tobiassen wrote in his calender: *21 February 2011, Narwhale, 45 individuals in Uummannaq Fjord off Igdlorssuit*. These hand-written observations constitute the most disaggregated data in the system.

Step 3. Interpreting the data at the local level

Once every three months, the NRC meets in the community. At this meeting, data and knowledge from the community's monitoring of natural resources are summarized by each member, and then discussed, and interpreted. Suggestions for management initiatives are also considered. The local interpretation is prompted by the filling-in of a summary form which, at the end of the meeting, is signed by the participants. Both data on dead and observations of live animals are accompanied by data on effort. The summary form has the following headings:

- Resource (e.g. Greenland halibut)
- Month and year (e.g. September 2010)
- Area (e.g. sea off Qaarsut, Uummannaq Fjord)
- Number of fishing or hunting days (e.g. six days)
- Fishing or hunting gear (e.g. dinghy, long-line)
- Fishing or hunting effort and catch (e.g. 600 hooks used on six fishing days; 3600 kg)
- Trend in relation to same time last year (e.g. increase)
- Importance of the finding (e.g. very important)
- Possible explanation (e.g. possible population increase) and
- Proposed action (e.g. none for the time being)

The filling-in of this summary form is a fundamental element of the system as it encourages self-evaluation of local observations and knowledge and, at the same time, promotes local discussion of trends, their possible reasons, and relevant actions.

Step 4. Proposing management initiatives

The proposals for management initiatives are presented at meetings of the Village Council and the local government authority. They consider whether there is a need for more knowledge or whether initiatives can be taken locally on the basis of the NRC results. The Village Council and local government authority are encouraged to take decisions about *what* should be done, by *whom* and *when*.

Step 5. Discussing the results at a community meeting

Once in a year, the NRC organizes a meeting with all people in the community with an interest in the environment. At this meeting, the results of the community's monitoring of resources and resource uses are presented. Proposed management actions are discussed and evaluated. During this meeting, others in the community have an opportunity to learn about the NRC's findings in their area. At the same time, the meetings allow for feedback from other community members, which can result in broad support for management actions.

How are the data handled?

In each community, the person responsible for stewardship of the data in the system is the local NRC coordinator. The system generates two kinds of data: (1) observations of resources and resource uses made by community members and (2) summary forms with a description of the proposed management decisions and the supporting data and analysis prepared by the NRC. Both types of data are

Table 1. Decisions that can be taken at the local (municipal) authority level within the current regulations in order to manage fish, seals, cetaceans, ungulates and birds in Greenland (Greenland Government 1996, 1999; Ministry of Fisheries, Hunting and Agriculture 2011).

Potential local authority decision	Fish	Seals*	Cetaceans	Ungulates†	Birds
Local time closure‡	■	■		■	■
Local area closure	■	■			■
Local restriction for specific methods and gear‡	■	■			■
Local adjustment of fishing operation	■				
Propose change to national quotas, seasons and bag limits	■		■	■	■
Make quotas sex- or age-specific				■	
Sub-divide quotas for specific sites				■	
Divide the quotas and bag-limits between part- and fulltime-hunters				■	■

Note: See Annex S4 for examples.
*Ringed seal, harp seal, hooded seal, bearded seal, †Caribou, musk ox, ‡within the government's overall framework in terms of fishing/hunting seasons, and permitted methods, boats and gear.

filed in ring-binders and stored in the municipal office in each community. The ring-binders of data constitute the system's main database. The data belong to the NRCs but the local authority and the central government can obtain copies.

Which decisions can be taken at the local level?

From the government's perspective, the starting point for this system was that it should encourage data-based decision-making on natural resources on the part of the local authority and the communities. However, early on it became clear that there was little knowledge available as to what local decisions could be taken without breaking the law (Haaland *et al.* 2005). We therefore assessed the current regulatory framework in order to identify potential decisions that local authorities could take for natural resource management.

We found that, for fish, seals, cetaceans, musk ox, caribou, and birds, the local government authority could take only a few decisions independently of the central government, namely:

1. Reducing the time or area and adjusting the methods and gear used to fish and hunt and
2. Sub-dividing the nationally set quotas and bag limits into smaller units specific to, e.g., the sex and age of animals, the hunting area, the hunting community, or the individual hunters' registration as either a full- or a part-time hunter (Table 1; examples in Annex S4).

Results from the first three years

What did the community members find?

In the first three years (2009–2011), a total of 33 fishermen, hunters, and environmentally interested people enrolled in the monitoring system. Most participants were men (94%). Eight community members contributed written

Table 2. Comparison of community members' perceptions and professional scientists' assessments of trends in abundance of sea-ice, two human activities and 21 populations of fish, mammals and birds in Disko Bugt, Uummannaq Fjord, and adjacent areas of North West Greenland 2009–2011.

Attributes	Perceptions*	Scientists' assessments	Source of scientists' assessments†	Correspondence
Fish				
Atlantic cod, D	‡	Few data	Siegstad 2011	NA
Wolffish *spp.*, D	↑	↑/⇔	Siegstad 2012	(✓)
Greenland halibut	↑	↓/⇔	Siegstad 2011, 2012	⊘
Marine mammals				
Ringed seal	↓	Few data	Boertmann 2007; Rosing-Asvid 2010	NA
Harp seal, D	↑	↑	Department of Fisheries and Oceans 2010; Rosing-Asvid 2010	✓
Narwhale	‡	Few data	North Atlantic Marine Mammal Commission 2012	NA
Humpback whale	↑	↑	Heide-Jørgensen *et al.* 2011	(✓)
Minke whale, D	↑	↑	Heide-Jørgensen *et al.* 2010	(✓)
Minke whale, U	⇔	Few data	No information	NA
Land mammals				
Arctic fox, D	↑	Few data	Boertmann 2007	NA
Caribou, N	⇔	⇔	Cuyler *et al.* 2005; Cuyler and Nymand 2011	✓
Musk ox, L	‡	Few data	No information	NA
Birds				
Snow goose, D	↑	↑	Boertman 2007	✓
Greenland white-fronted goose, U	↓	↓	Boertmann 2007; Boyd and Fox 2008	✓
Canada goose	↑	↑	Bennike 1990; Fox *et al.* 1996; Boertman 2007	✓
Common eider	↑	↑	Chaulk *et al.* 2005; Merkel 2010	(✓)
White-tailed eagle, D	↑	Few data	No information	NA
Large gulls**, D	↑	Few data	Boertmann 2007	NA
Arctic tern, D	↑	⇔	Boertmann 2007; Egevang and Frederiksen 2011	⊘
Brünnich's guillemot, breeding	↓	↓	Burnham *et al.* 2005; Labansen and Merkel 2012	✓
Little auk, D	↑	Few data	Egevang and Boertmann 2001; Boertmann 2007	NA

Table 2. Continued.

Attributes	Perceptions*	Scientists' assessments	Source of scientists' assessments†	Correspondence
Other				
Winter sea-ice††, U	↓	↓	Danish Meteorological Institute	✓
Offshore ships, U	↑	↑	Arctic Marine Shipping Assessment 2009	(✓)
Trawling, D	↑	Few data	No information	NA

Note: ↑, increased abundance; ↓, declining abundance; ⇔, no major change in the abundance; ‡, increased abundance reported in some areas, decline in other areas; Few data, there are little or no abundance data available; ✓, correspondence between community members' and scientists' assessments; (✓), probable correspondence between community members' and scientists' assessments but the time, area and/or temporal/spatial scale of the assessments do not match; ⊘, no correspondence. D, Disko Bugt; L, Naternaq/Lersletten and Svartenhuk; N, Nassuttooq/Nordre Strømfjord; NA, not applicable; U, Uummannaq Fjord.
*The community members' findings are presented in Annex S5.
†The scientists' assessments are summarized in Annex S7. ** Great black-backed, Iceland, and glaucous gull. †† 2010. See supporting information for literature cited.

observations from their fishing and hunting trips, whereas the other contributed their observations verbally during the NRC meetings. The community members summarized their observations and knowledge of trends in abundance for 24 attributes, including sea-ice, trawling, shipping and three fish, nine mammal, and nine bird populations. The community members' findings are presented in Annex S5 and summarized in Table 2. The filled-in summary forms from the NRC meetings are provided in Annex S6 for the purpose of replicating and building on this work. For most of the attributes, the community members reported positive trends in abundance in Disko Bugt, Uummannaq Fjord, and adjacent areas (63%; $n = 24$).

For three species, the NRCs provided information on body conditions: harp seal, minke whale, and caribou. Harp seals in Disko Bugt were reported to be frequently 'thin' and in 'poor' body condition. Minke whales in the same area were 'generally smaller in size than before,' and caribou in Nassuttooq in 2011 were described as in 'poor' condition (Annex S5).

The NRCs reported the community members' perceptions of ecological dynamics and relationships related to 13 taxa of fish, mammals, and birds. Their reports included five distinct types of dynamics and relationships: (1) threats to wildlife populations; (2) species competing with each other (Greenland white-fronted goose, Canada goose); (3) species of nuisance to dinghy traffic and fishing (multiple); (4) food choice of wildlife species (Greenland shark); and (5) 'natural phenomena' such as terns abandoning their eggs simultaneously across wide areas. The community members described the following threats to wildlife populations: sea-floor degradation from shrimp trawling in shallow areas (wolffish), noise from shipping traffic (narwhale), disturbance from tourists (caribou), and by-catch in gill nets (guillemots) (Table 3).

The ultimate objective of the system is to guide and improve decision-making on natural resource management. In order to assess the performance of the system, we therefore kept track of management proposals resulting from it. A total of 14 distinct recommendations were made for 12 resources (Annex S5). The proposals

Table 3. Comparison of community members' perceptions of ecological dynamics and relationships in North West Greenland 2009–2011, with information from the peer-reviewed literature.

Species	Community members' perceptions	Scientists' information*	Correspondence
Striped/ spotted wolffish	'Wolffish are vulnerable to sea floor degradation'	Freese *et al.* 1999; Lachance *et al.* 2010	✓
Greenland shark	'Greenland shark is attracted to rotten fish'	Leclerc *et al.* 2011	✓
Narwhale	'Narwhale is disturbed by shipping traffic'	Nowacek *et al.* 2007	✓
Humpback whale	'Humpback whales pose a threat to dinghy traffic'	Laist *et al.* 2001; Parsons 2012	✓
Caribou	'Caribous are disturbed by hiking tourists'	Reimers *et al.* 2006	✓
Geese	'Greenland white-fronted and Canada goose are competing with each other'	Boyd and Fox 2008	✓
Arctic tern	'Some years, thousands of terns abandon their eggs'	Monaghan *et al.* 1989; Erikstad *et al.* 1998; Egevang and Frederiksen 2011	✓
Guillemot	'Historically, the decline in breeding Brünnich's guillemot in West Greenland was caused by by-catch in nets'	Tull *et al.* 1972†	(✓)
Multiple	Harp seal, narwhale, humpback whale, and great black-backed, Iceland, and glaucous gull constitute a competition or nuisance to the fishing of Atlantic cod and Greenland halibut (Disko Bugt)	Perkins *et al.* 1982; Finley *et al.* 1990; Lawson *et al.* 1995; Johnson *et al.* 2005; Laidre and Heide-Jørgensen 2005; Witteveen *et al.* 2006; Neilson *et al.* 2009	(✓)

Note: ✓, potential correspondence between community members' perceptions and biologists' assessments; (✓), partial correspondence between community members' perceptions and biologists' assessments.
*See Annex S8 for a summary of the scientific literature; †Other scholars have attributed this decline to (still continuing) summer hunting and disturbance at the breeding colonies (Falk and Kampp 1997; Labansen *et al.* 2013). See supporting information for literature cited.

relate to the setting of quotas for harvesting resources (2 proposals), the changing of hunting seasons (5), the need for research into particular topics (3), the regulation of fisheries through the establishment of municipal bylaws (2), and other types of actions (2). As of June 2013, the local municipal authority had reviewed and made decisions regarding 11 of these 14 proposals.

Correspondence between community members' and professional scientists' assessments

Are the local reports biased by 'conflicts of interest' when harvesters are themselves monitoring the resource? To explore this question, we compared the local reports on abundance, body conditions and ecological dynamics, with data produced by

scientists who do not have a direct harvest interest. We obtained such data from peer-reviewed literature, technical reports, and advisory information prepared by scientists for the Greenland Government. If the local reports are biased by harvest interests, we would expect the locals' findings to differ substantially from scientists' findings.

First, we compared locals' and scientists' reports of trends in the abundance of the 24 attributes that were summarized by the community members in the NRCs from 2009 to 2011 (Table 2; Annex S7). Unfortunately, we could only find scientist-executed studies from the same areas and at the same time for four attributes (17%; $n = 24$). Nevertheless, scientists' data from adjacent areas can provide a preliminary indication of the degree of correspondence between the locals' and professional scientists' reports. We found that, despite considerable differences in the way their knowledge is obtained, the community members and the professional scientists produced similar results for 12 attributes: spotted wolffish, harp seal, humpback whale, minke whale, caribou, snow goose, Greenland white-fronted goose, Canada goose, common eider, breeding Brünnich's guillemot, winter sea-ice, and shipping. We found that, for two populations, nearshore Greenland halibut and breeding Arctic tern, there was disagreement between local and scientists' reports of trends in abundance. For 10 attributes, we were unable to find data from professional scientific surveys to allow for a comparison with the community members' findings.

Second, for body conditions, community members provided information on harp seal, minke whale, and caribou (Annex S5). We were unable to locate reports by professional scientists on harp seal and minke whale but we found information on caribou from the same year and area (Cuyler and Nymand 2011), and these results matched the community members' findings. For ecological dynamics and relationships, we found that none of the 13 relationships reported by the community members were directly dismissed by the peer-reviewed scientific literature (Table 3; Annex S8).

Discussion

We have described the theoretical framework and methods used in the local documentation and management system in North West Greenland, and we have presented the results from the first three years of monitoring. Our analysis shows that the system has engaged community members in discussions of their observations and knowledge of the natural resources. Fishers, hunters, and other environmentally interested people in the rural communities are using their own observations and knowledge to keep track of environmental changes and are participating meaningfully in decision-making processes around natural resource management. Moreover, the local authority is taking actions on the basis of the community members' proposals.

The prescribed methods have not, however, been fully complied with. First, only a minority (24%) of the NRC members wrote down their observations. Most hunters and fishers preferred to present their observations verbally at the meetings of the NRCs. Second, when there were long periods with no fishing and hunting, there were no meetings among the NRC members so the intended schedule of quarterly meetings was not fulfilled. Third, although it was the intention that the NRC members should be chosen by the Village Council in each community, in

practice it was those community members who were interested that were enrolled in the system. Fourth, the local NRC coordinators did not always give a copy of the summary forms with the list of possible management initiatives to the Village Council for endorsement before submitting the forms to the municipality and the central government. A continued dialogue is needed between the central government, the local authority, and the NRCs.

Despite strong efforts to be objective in our comparison of community members' and professional scientists' reports, some areas remained subjective. First, the local reports may be based not only on local observations and local knowledge but may also have been influenced by publicity surrounding scientific findings that have become accepted knowledge in a local community (Huntington *et al.* 2004). Second, our approach was retrospective and opportunistic, and insufficient match between the area, time, and geographical and temporal scale of the local and scientists' reports may have affected the comparisons. Third, our main comparisons were between community members' perceptions and professional scientists' methods, which mainly included fish-biomass assessments, aerial surveys, remote-sensing, and breeding bird censuses (Annex S7). These methods are also recognized to have weaknesses in terms of capturing 'true' trends in the abundance of resources (e.g. Caughley 1974). Nevertheless, our results provide preliminary support for the idea that community-based monitoring in the Arctic can yield locally relevant results that can be as reliable as those derived from professional scientist-executed monitoring.

Many of the NRC recommendations involve increasing the harvest of other species because these are perceived to constitute threatening competition or a nuisance to Atlantic cod and Greenland halibut gillnet and long-line fisheries (harp seal, narwhale, humpback whale, and great black-backed, Iceland, and glaucous gull). The management decisions proposed by the locals for these species were: support marketing opportunities for whole seals, permit catch of solitary narwhales during summer outside of the quota system, increase the quota for humpback whale, and expand the egg collection season for colonies of large white gulls only (Annex S5). Whether these proposed decisions will have the intended effect on the cod and halibut fishery – and whether the severity of the competition justifies the proposed actions – is beyond the scope of this paper.

Our findings on the consistency of local reports relative to biological assessments concur with previous studies of common eider, harlequin duck, and ivory gull in the Arctic (Gilchrist *et al.* 2005). Gilchrist *et al.* (2005) also compared locals' and scientists' reports of the breeding population of Brünnich's guillemot in Greenland. Hunters and scientists agreed that the breeding numbers in Upernavik Region had declined but disagreed over the cause of the decline. Most hunters attributed it to the fact that the colonies had moved, whereas the scientists, based on aerial and boat surveys of the entire West coast of Greenland, concluded that no new colonies had been initiated and that there had been an overall decline in the breeding population (Gilchrist *et al.* 2005). It is therefore important that monitoring at the local scale is backed up by monitoring by scientists or community members at a larger scale so as to be able to determine whether locally detected changes reflect broader changes in abundance or in the range of the resources.

Incentives for the participants

Why is there interest from rural fishers and hunters in participating in the monitoring system? Initially, a workshop was held to discuss the monitoring plans with the local authorities and with representatives of the communities in Disko Bugt and Uummannaq Fjord. It was made clear that the community monitoring was intended to serve as an *opportunity* provided by the government for use only by those communities and fishers and hunters who were interested. Direct payment of participants, which is frequent in other government and externally funded initiatives in the country, would be impossible for the government to sustain.

Most people at the workshop decided that they would still like to enroll in the system. We believe there are several reasons as to why community members would be keen on participating as volunteers in the system. First, they are keen on participating because of their interest. Fishing and hunting are a central part of the life and identity of the communities (Dahl 2000; Nuttall 2005). For some of the participants, fishing and hunting constitute their mainstay. For others, they provide additional incomes, while their principal income comes from a paid job. The status and abundance of the wildlife populations and the use of the living resources are topics of the utmost importance, even to those who are not fishers and hunters. The monitoring system was designed to build on what people are interested in. For instance, the monitoring targets are not selected by scientists or by the government. Each NRC decides among its members – on the basis of their interests and with advice from government facilitators – which species and resource uses they will keep track of. While one might think that this would lead to a wide array of different monitoring targets, which would complicate analysis, the four NRCs all selected the same species and resource uses to record. From other countries, it is also known that the improved status from being part of a community committee can be an important incentive for some community members (Topp-Jørgensen *et al.* 2005).

Second, participating in the community monitoring provides an opportunity for the community members' insights and knowledge to be used and their voices heard (Funder *et al.* 2013). In Greenland, as in other parts of the Arctic, discrepancies between the authorities' perceptions of the status of the environment and the local peoples' knowledge and perceptions have, in some areas, led to frustration among community members and to limited local understanding and acceptance of government decisions (Sejersen 2003). The government would therefore like to increase the involvement of the 'users' in the government's decision-making. Occasional phone calls from fishers and hunters telling government staff about observations of huge numbers of wildlife are impossible to use in government decisions. In contrast, direct-count data, compiled by the same people at the same sites over an extended time frame, especially when written down and supported by local interpretation and analysis, can provide very useful information for the government (e.g. Merkel 2010), especially where conventional scientific monitoring programs are providing infrequent or no information.

Third, it is easy to participate. There is little extra work associated with the community monitoring routines for the participants. The work can easily be integrated into the existing day-to-day activities of most community members. The routines only require that the community members note their observations on a calendar, and that they regularly interpret their observations and discuss possible management decisions with the other participants in the community. The monitoring routines also do not require the use of special equipment. The only equipment

Table 4. Tenets for an indigenist paradigm for research programs, formulated by Pulsifer *et al.* 2011 (adapted from Barnhardt and Kawagley 2001; Wilson 2007, 2008).

1.	Respect, reciprocity and responsibility of the researchers.
2.	Research designed and executed in partnership with, if not led by, indigenous communities.
3.	Research leads to a better understanding of, and provision for, indigenous people.
4.	Ontology and epistemology focus on relationships between things or 'relationality' (e.g. ourselves, others, environment, spirit, ideas) rather than the things themselves.
5.	Researchers remain accountable for the relationships and transformations that they initiate.
6.	Recognition of indigenous languages and cultures as living processes.
7.	Rejection of the notion of the objective observer; knowledge is produced in a cultural and political context.
8.	The emergence of knowledge through a synthesis of experience, observation and experimentation.
9.	Cooperative rather than oppositional knowledge production processes.
10.	Use of metaphors and symbolism.
11.	Articulating what the indigenist research paradigm is rather than comparing with other knowledge production systems; and understanding the context of data production.

needed is pencils, a standard calendar, and, if available, a pair of binoculars and a mobile phone with camera (for documentation purposes).

Is the system culturally appropriate?

To explore whether the system is culturally appropriate, we examined its relationship to an indigenist paradigm for research programs presented in Table 4. The methods of the system form part of a management approach that builds on the existing local and indigenous institutions and participants in North West Greenland. The system is designed precisely to enable natural resource management decisions at appropriate levels of government to respond to community-identified issues. The local authorities' actions, based on the NRCs' proposals, promote respect for the observations and knowledge of the NRCs and reciprocity between different actors (point 1, Table 4) and, at the same time, increase the ability of the community members to propose management decisions that are realistic and well-supported by their field observations and knowledge. Local indigenous community members in the NRCs are taking a lead in the system (point 2). However, both the Village Council and the local and central government have the option of rejecting the NRC proposals. This is, however, no different from other relationships in society; one can propose and argue for a government intervention but whether it will be followed depends on what the democratically elected government decides, on the basis of technical input from its staff. The system leads to better provision for indigenous and other local communities by encouraging a more inclusive management of natural resources (point 3). The local observations provide insights into ecological relationships (point 4). Central government and local authority staff involved in the system provide regular feedback to the communities on their proposed management decisions, and whether they have been acted upon or not, and why (point 5). The system uses indigenous language and emphasizes oral culture (point 6), particularly during the discussions in the NRCs, when data interpretation is undertaken. The system attempts to make it explicit as to who made a specific observation (point 7). The local knowledge is not merely reduced to 'anecdotal information' as has often

been the case in natural science research papers in the past but is given credit as a source of independent environmental information. The system thereby helps to recognize the cultural, economic, and political context of data production. The system builds on knowledge generated both by experience and direct observations but not on experimentation (point 8). The NRC discussions and annual community meetings of the system encourage open dialog. These discussions and meetings are highly cooperative and help enable the incorporation of observation data and different perspectives into the knowledge production processes (point 9). The NRC discussions use the local context, including culturally rooted understanding of species, areas, and practices (point 10). The interpretation of data in the system is undertaken via an inclusive and open process (point 11). Some species are, however, subject to detailed international management regimes that the government has to comply with. The management proposals emanating from the system are therefore subject to scrutiny by either the local government authority or the central government before they can be acted upon. In conclusion, the system includes most of the aspects that are believed to make initiatives culturally appropriate.

Desirable further developments

In the long run, communities are only likely to continue monitoring if their efforts continue to be acknowledged, accepted and included in the decision-making processes at local and central levels. If the government wants to provide greater opportunities for NRCs and the local authorities to take decisions on the management of natural resources, some form of dispensation will be necessary from the government. To help this process, we provide examples of possible dispensations for Greenland halibut, caribou, musk ox, and Arctic tern (Annex S4).

In the pilot communities, the management proposals that follow the monitoring activities have mainly been reactions to immediate threats or locally observed trends in the natural resources rather than to trends revealed by analyses of large data-sets across several areas. At present, the NRCs do make numerical, quantitative analyses, and comparisons across multiple years based on observations and local knowledge from their fishing and hunting areas. However, even with more capacity development and training, it is unlikely that the NRCs will ever undertake comparisons across many geographical areas on a municipal or national scale, using very large data-sets.

At the national level, however, there is considerable scope for collecting the local observations and using them to track wider trends in the abundance of resources while at the same time increasing local people's input into higher-level decision-making (Danielsen *et al.* 2013). Data from local monitoring could potentially be aggregated to generate larger-scale overviews of, for instance, species range and phenology, habitat condition, opportunities and threats, impacts of management interventions, and delivery of benefits such as wildlife resources to the local communities from the natural ecosystems.

For some species and populations (e.g. coastal populations of Atlantic cod, arctic fox, some populations of caribou and musk ox, snow goose, Canada goose, and white-tailed eagle), community-based monitoring is perhaps the only source of information, and hunters cover surprisingly large areas with outboard engines on their dinghies (Due and Ingerslev 2000).

Professional biologists' research will, however, remain very much needed, for instance, in determining safe thresholds for harvesting wildlife populations and

providing other quantitative information on the abundance of resources where management requires 'exact' knowledge of population numbers. This holds true especially for Greenland white-fronted goose and breeding Brünnich's guillemot, which are both rapidly declining in numbers in this part of Greenland (Boertmann 2007; Labansen and Merkel 2012; and local knowledge in this study; Annex S5–S6) as well as for polar bear, walrus, and cetaceans, which are included in international management regimes where the boards rely on scientific methods (Polar Bear Specialist Group, North Atlantic Marine Mammal Commission, International Whaling Commission). Community-based monitoring has the potential to provide a second-informed opinion on some of those species. It likewise has potential to contribute important knowledge about trends in abundance during periods when GINR is not monitoring.

A future national monitoring strategy in Greenland should therefore combine several monitoring methods, including conventional scientific methods and community-based monitoring approaches such as the present system. If the current local system were to be transformed into a national system for using local observations and knowledge to improve resource management in Greenland, it would require the establishment of strong linkages between the local and the national data management systems. It would also require expanding the local monitoring to more communities, geographically spread across Greenland.

Experience from abroad suggests that the scope for linking local and national natural resource monitoring may best be explained by thinking about contributions and relative benefits (Pratihast and Herold 2011). If there are not benefits for both sides, the local–national linkages are unlikely to be sustained. On the other hand, if both sides contribute and benefit, a situation can be created that can help to stimulate and sustain collaboration. In figure 2, we conceptualize how communities can be linked to national monitoring in Greenland in a mutually beneficial way. If

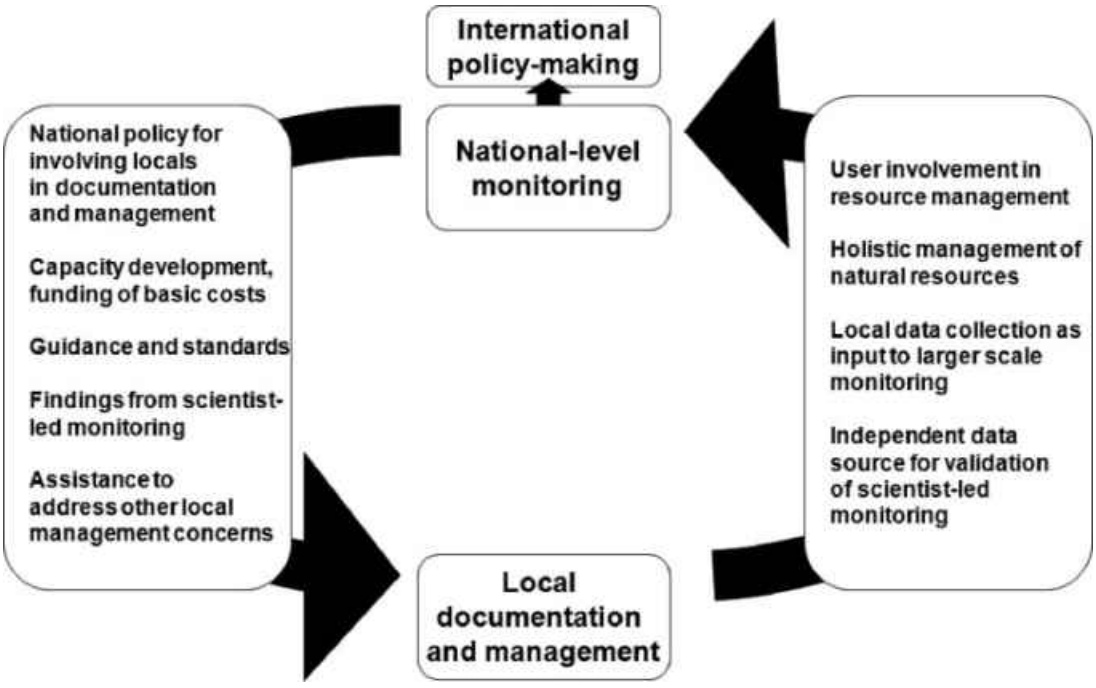

Figure 2. Contributions to and benefits of local documentation and management for national-level monitoring of natural resources in Greenland.

the current local system were to be transformed into a networked, national system, the central government would need to provide a policy that sets aside government staff time and funds, develop minimum requirements for local monitoring, and establish a data infrastructure system so that locally acquired data, similar to professional scientists' data, can be uploaded, and made publicly available subject to the approval of the data-providing community members. In return, local monitoring could encourage community engagement in decision-making and holistic approaches to resource management, and contribute data to national policy-making (Sutherland *et al.* 2013). Such efforts would, however, add costs to a system that is currently paper-based and low-tech, and the only cost of which is the limited time of administrators at municipal and central government level.

Conclusions

In the social science literature, there is growing support for the idea that, when citizens are engaged in collecting, analysing, and sharing data on the environment, they will build their own capacity to adaptively manage local environmental resources (discussion in Tidball and Krasny 2012). Whereas community-based documentation cannot replace scientists' monitoring of Greenland's natural resources, our experience suggests there is great potential for combining the two approaches. Both have roles to play and partnerships could only be beneficial (Huntington *et al.* 2004). If properly coordinated, local monitoring can provide information on those species and populations that matter most to fishermen, hunters, and environmentally interested community members. The resulting dialog between local communities and authorities can facilitate a better differentiation of fishing and hunting periods and quotas geographically and help adjust the resource management to the changing environmental conditions. The dialog can also lead to a common understanding of local natural resource use and an increased ownership and acceptance of regulatory actions, whether implemented by the local or the national level.

Acknowledgments

We thank the communities of Akunnaaq, Kitsissuarsuit, Ilulissat and Qaarsut and the local coordinators M. Knudsen, T. Mølgaard, G. Nielsen and K. Tobiassen. We would also like to thank S. Geisler, P. Kruuse and H. Rafn of Qaasuitsup Kommunia. We are grateful to A. Jessen for advice and support and to A. Blytmann, P. Egede, L.K. Holm, A. Landa, Z.G. Larsen, J. Madsen, S. Olsvig, B. Pálsson and F. Ugarte for advisory group contributions. J. Jakobsen, Danish Meteorological Institute, and F. Ugarte kindly provided unpublished data. We thank M. Anzén, A. Asvid-Rosing, R. Bonney, S. Brofeldt, T. Callaghan, H.P. Christensen, C. Cuyler, S. and J. Gearheard, M. Gill, V. Gofman, K. Guldbæk, A. Gran, B. Hansen, K. Hansen-Craik, S. Jepson, A. Jerimiassen, D.R. Kapijimpanga, E. Kruemmel, L. Kullerud, M. Labansen, N.M. Lund, B. Lyberth, A. Lynge, H. McCann, H. Meltofte, T. Mustonen, M.R. Nielsen, B. Pedersen, F. Pedersen, R.O. Rasmussen, H.S. Møller, F. Sejersen, M. Svoboda, I. Thaulow, K. Williamsson, A. Yefimenko and K. Zaunberger for encouragement. J. Fjeldså, H. Huntington, F. Merkel, M.K. Poulsen and P. Pulsifer provided comments. This work was funded by the Nordic Council of Ministers, the

Government of Greenland, Nordisk Fond for Miljø og Udvikling and the European Commission. We dedicate this paper to the memory of Jens Bagger who participated in the development of the system.

Supplemental data

Supplemental data for this article can be accessed here.

References

Arctic Council, 2002–2013, Inari Declaration 2002; Reykjavik Declaration 2004; Salakhard Declaration 2006; Tromsø Declaration 2009; Nuuk Declaration 2011; Kiruna Declaration 2013. Available online at: http://eppr.arctic-council.org/content/reports (Accessed 10 June 2013).

Barnhardt, R., and Kawagley, A., 2001, *Culture, Chaos, and Complexity: Catalysts for Change in Indigenous Education* (Fairbanks, Alaska: Alaska Native Knowledge Network).

Berkes, F., 2012, *Sacred Ecology*, 3rd edition (New York, NY: Routledge).

Berkes, F., Colding, J., and Folke, C., 2000, Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, **10**(5), pp. 1251–1262.

Boertmann, D., 2007, Greenland Red List 2007 (in Danish) *Grønlands Rødliste 2007* (Nuuk, Greenland: DMU and Greenland Home Rule).

Caughley, G., 1974, Bias in aerial survey. *Journal of Wildlife Management*, **38**(4), pp. 921–933.

Cuyler, C., and Nymand, J., 2011, *Caribou harvest advice for autumn 2011/winter 2012 West Greenland: Naternaq, North, Central, South & Paamiut Regions & four other regions: Inglefield-Prudhoe Lands, Olrik Fjord, Nuussuaq Halvø, Ivittuut* (Nuuk, Greenland: Greenland Institute of Natural Resources).

Dahl, J., 2000, *Saqqaq. An Inuit Hunting Community in the Modern World* (Toronto, Buffalo, London: University of Toronto Press).

Danielsen, F., Balete, D.S., Poulsen, M.K., Enghoff, M., Nozawa, C.M., and Jensen, A.E., 2000, A simple system for monitoring biodiversity in protected areas of a developing country. *Biodiversity and Conservation*, **9**, pp. 1671–1705. Available online at: www.monitoringmatters.org (Accessed 10 January 2014).

Danielsen, F., Burgess, N.D., and Balmford, A., 2005, Monitoring matters: Examining the potential of locally-based approaches. *Biodiversity and Conservation*, **14**, pp. 2507–2542. Available online at: www.monitoringmatters.org (Accessed 10 January 2014).

Danielsen, F., Jensen, P.M., Burgess, N.D., Coronado, I., Holt, S., Poulsen, M.K., Rueda, R.M., Skielboe, T., Enghoff, M., Hemmingsen, L.H., Sørensen, M., and Pirhofer-walzl, K., 2014, Testing focus groups as a tool for connecting indigenous and local knowledge on abundance of natural resources with science-based land management systems. *Conservation Letters*. In press (March 2014).

Danielsen, F., Pirhofer-walzl, K., Adrian, T., Kapijimpanga, D., Burgess, N., Jensen, P.M., Bonney, R., Funder, M., Landa, A., Levermann, N., and Madsen, J., 2013, Linking public participation in scientific research to the indicators and needs of international environmental agreements. *Conservation Letters*, **7**, pp. 12–24.

Due, R., and Ingerslev, T., 2000, Nature Conservation in Greenland. Technical Report Number 29 (in Danish) *Naturbeskyttelse i Grønland. Teknisk Rapport nr. 29*. (Nuuk, Greenland: Grønlands Naturinstitut).

Ferguson, M.A.D., Williamson, R.G., and Messier, F., 1998, Inuit knowledge of long-term changes in a population of Arctic tundra caribou. *Arctic*, **51**, pp. 201–219.

Folke, C., 2004, Traditional knowledge in social-ecological systems. *Ecology and Society*, 9(3), p. 7.

Funder, M., Danielsen, F., Ngaga, Y., Nielsen, M.R., and Poulsen, M.K., 2013, Reshaping conservation: The social dynamics of participatory monitoring in Tanzania's community-managed forests. *Conservation and Society*, **11**(3), pp. 218–232.

Génsbøl, B., 2004, *A Nature and Wildlife Guide to Greenland* (Copenhagen, Denmark: Gyldendal).

Gilchrist, G., Mallory, M., and Merkel, F., 2005, Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. *Ecology and Society*, **10**(1), p. 20.

Gofman, V., 2010, *Community Based Monitoring Handbook: Lessons from the Arctic*. CAFF CBMP Report No. 21 (Akureyri, Iceland: CAFF).

Gofman, V., and Smith, M., 2009, *Bering Sub-Sea Network Pilot Phase Final Report*. CAFF Monitoring Series Report No. 2 (Akureyri, Iceland: CAFF).

Greenland Government, 1996, *Landstingslov nr. 18 af 31. oktober 1996 om fiskeri*. Available at: www.lovgivning.gl/gh.gl-love/dk/1996/Ltl/ltl_nr_18-1996_dk.htm (Accessed 20 January 2013).

Greenland Government, 1999, *Landstingslov nr. 12 af 29. oktober 1999 om fangst og jagt, §2 stk. 3*. Available at: http://dk.nanoq.gl (Accessed 20 February 2013).

Greenland Institute of Natural Resources [GINR], 2013, *Greenland Institute of Natural Resources*. Available at: http://www.natur.gl/en/ (Accessed 6 June 2013).

Haaland, H., Skogen, K., Landa, A., Loeks, D., Andersen, O., Aastrup, P., Egevang, C., and May, R., 2005, Delegation of management responsibility – living resources in Greenland (in Danish) *Uddelegering af forvaltningsansvar – levende ressourcer i Grønland*. NINA Rapport 6 (Trondheim, Norway: Norwegian Institute for Nature Research).

Huntington, H.P., 1998, Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge. *Arctic*, **51**, pp. 237–242.

Huntington, H.P., 2000, Using traditional ecological knowledge in science: Methods and applications. *Ecological Applications*, **10**(5), pp. 1270–1274.

Huntington, H.P., 2011, Arctic science – the local perspective. *Nature*, **478**, pp. 182–183.

Huntington, H.P. (Ed.), 2013, Provisioning and cultural services. In *Arctic Biodiversity Assessment. Status and Trends in Arctic biodiversity*, H. Meltofte (Ed.), pp. 592–626 (Akureyri, Iceland: Conservation of Arctic Flora and Fauna).

Huntington, H.P., Callaghan, T., Fox, S., and Krupnik, I., 2004, Matching traditional and scientific observations to detect environmental change: A discussion on Arctic terrestrial ecosystems. *Ambio*, **33**, pp. 18–23.

Johannes, R.E., Freeman, M.M.R., and Hamilton, R.J., 2000, Ignore fishers' knowledge and miss the boat. *Fish and Fisheries*, **1**(3), pp. 257–271.

Johnson, N., Alessa, L., Behe, C., Danielsen, F., Gearheard, S., Gofman, V., Kliskey, A., Mustonen, T., Pulsifer, P., and Svoboda, M., 2014, Strengthening community-based monitoring in the Arctic. Key challenges and opportunities. A Community White Paper Prepared for the Arctic Observing Summit 2013. *Arctic* under review (March 2014).

Knopp, J., Pokiak, F., Gillman, V., Porta, L., and Amos, V., 2013, Inuvialuit Settlement Region community-based monitoring program: Community-driven monitoring of locally important natural resources. A Community White Paper Prepared for the Arctic Observing Summit 2013. Available at: http://www.arcticobservingsummit.org/pdf/white_papers/isr_community-based_monitoring_program.pdf (Accessed 20 June 2013).

Krupnik, I., Apangalook, L. Sr., and Apangalook, P., 2010, "It's cold, but not cold enough": Observing ice and climate change in Gambell, Alaska, in IPY 2007–2008 and beyond. In *SIKU: Knowing our Ice: Documenting Inuit Sea-Ice Knowledge and Use*, I. Krupnik, C. Aporta, S. Gearheard, G.J. Laidler, and L.K. Holm (Eds.), pp. 81–114 (Dordrecht, The Netherlands: Springer).

Labansen, A.L., and Merkel, F.R., 2012, Kolonien i Diskobugten i fare for udryddelse. *Sermitsiaq*, 11 May.

Larsen, T.S., Kurvits, T., and Kuznetsov, E., 2011, *Lessons Learned from ECORA – An Integrated Ecosystem Management Approach to Conserve Biodiversity and Minimize Habitat Fragmentation in the Russian Arctic*. CAFF Strategy Series Report No. 4 (Akureyri, Iceland: CAFF).

Meltofte, H. (Ed.), 2013, *Arctic Biodiversity Assessment*. Status and trends in Arctic biodiversity (Akureyri, Iceland: Conservation of Arctic Flora and Fauna).

Merkel, F.R., 2010, Evidence of recent population recovery in common eiders breeding in Western Greenland. *Journal of Wildlife Management*, **74**(8), pp. 1869–1874.

Merkel, F.R., 2011, *Gillnet Bycatch of Seabirds in Southwest Greenland, 2003–2008*. Technical Report No. 85 (Nuuk, Greenland: Greenland Institute of Natural Resources).

Ministry of Fisheries, hunting and agriculture, 2011, *Jagttider*. Available online at: http://dk.nanoq.gl/Emner/Erhverv/Erhvervsomraader/Fangst_og_Jagt/Jagttider.aspx (Accessed 20 January 2012).

Ministry of fisheries, hunting and agriculture, 2014, *Piniakkanik sumiiffinni nalunaarsuineq*. Available online at: www.pisuna.org (Accessed 10 January 2014).

Moller, H., Berkes, F., Lyver, P.O., and Kislalioglu, M., 2004, Combining science and traditional ecological knowledge: Monitoring populations for co-management. *Ecology and Society*, **9**, p. 2.

Mustonen, T., and Mustonen, K., 2011. *Eastern Sámi Atlas* (Vaasa, Finland: Snowchange Cooperative).

Nielsen, M.R., 2009, Is climate change causing the increasing narwhal (*Monodon monoceros*) catches in Smith Sound, Greenland? *Polar Research*, **28**, pp. 238–245.

Nuttall, M. (Ed.), 2005, Hunting, herding, fishing, and gathering: Indigenous peoples and renewable resource use in the Arctic. In *ACIA. Arctic Climate Impact Assessment*, pp. 649–690 (New York, NY: Cambridge University Press).

Oskal, A., Turi, J.M., Mathiesen, S.D., and Burgess, P., 2009, *EALÁT. Reindeer Herders Voice: Reindeer Herding, Traditional Knowledge and Adaptation to Climate Change and Loss of Grazing Lands* (Kautokeino/Guovdageadnu, Norway: International Centre for Reindeer Husbandry).

Post, E., Forchhammer, M.C., Bret-Harte, M.S., Callaghan, T.V., Christensen, T.R., Elberling, B., Fox, A.D., Gilg, O., Hik, D.S., Høye, T.T., Ims, R.A., Jeppesen, E., Klein, D.R., Madsen, J., McGuire, A.D., Rysgaard, S., Schindler, D.E., Stirling, I., Tamstorf, M.P., Tyler, N.J.C., van der Wal, R., Welker, J., Wookey, P.A., Schmidt, N.M., and Aastrup, P., 2009, Ecological dynamics across the Arctic associated with recent climate change. *Science*, **325**(5946), pp. 1355–1358.

Pratihast, A.K., and Herold, M., 2011, Community Based Monitoring and potential links with National REDD+ MRV. Input paper no. 1 for the FCPF workshop "Linking community monitoring with national MRV for REDD+'", 12–14 September 2011, Mexico City (Mexico: Universidad Nacional Autónoma de México).

Pulsifer, P.L., Laidler, G.J., Taylor, D.R.F, and Hayes, A., 2011, Towards an indigenist data management program: Reflections on experiences developing an atlas of sea ice knowledge and use. *The Canadian Geographer*, **55**(1), pp. 108–124.

Pulsifer, P.L., Pecl, G., and Huntington, H.P., 2014, Introduction: local and traditional knowledge and data management in the Arctic. *Polar Geography*, **37**(1), pp. 1–4.

Riedlinger, D., and Berkes, F., 2001, Contributions of traditional knowledge to understanding climate change in the Canadian Arctic. *Polar Record*, **37**, pp. 315–328.

Russell, D.E., Svoboda, M.Y., Arokium, J., and Cooley, D., 2013, Arctic Borderlands Ecological Knowledge Cooperative: can local knowledge inform caribou management? Rangifer 33 Special Issue No. 21. Available online at http://septentrio.uit.no/index.php/rangifer/article/view/2530 (Accessed 28 February 2014).

Sejersen, F., 2003, Greenlands nature management (in Danish) *Grønlands naturforvaltning* (Copenhagen, Denmark: Akademisk Forlag).

Spellerberg, I.F., 2005, *Monitoring Ecological Change* (Cambridge, UK: Cambridge University Press).

Statistics Greenland, 2013, *Statistics Greenland.* (Nuuk, Greenland: Statistics Greenland). Available online at: www.stat.gl/default.asp?lang=en (Accessed 12 June 2013).

Sutherland, W.J., Gardner, T.A, Haider, L.J., and Dicks, L.V., 2013, How can local and traditional knowledge be effectively incorporated into international assessments? *Oryx*, in press, **48**, pp. 1–2.

Tidball, K.G., and Krasny, M., 2012, A role for citizen science in disaster and conflict recovery and resilience. In *Citizen Science*, J.L. Dickinson and R. Bonney, (Eds.), pp. 226–233 (Ithaca, NY: Cornell Press).

Topp-Jørgensen, E., Poulsen, M.K., Lund, J.F., and Massao, J.F., 2005, Community-based monitoring of natural resource use and forest quality in montane forests and Miombo woodlands of Tanzania. *Biodiversity and Conservation*, **14**(11), pp. 2653–2677.

Weatherhead, E., Gearheard, S., and Barry, R.G., 2010, Changes in weather persistence: Insight from Inuit knowledge. *Global Environmental Change*, **20**(3), pp. 523–528.

Wilson, S., 2007, Guest editorial: What is an indigenist research paradigm? *Canadian Journal of Native Education*, **309**, pp. 193–195.

Wilson, S., 2008, *Research is Ceremony: Indigenous Research Methods* (Black Point, NS: Fernwood).

APPENDIX XI

Danielsen, F., Skutsch, M., Burgess, N.D., Jensen, P.M., Andrianandrasana, H., Karky, B., Lewis, R., Lovett, J.C., Massao, J., Ngaga, Y., Phartiyal, P., Poulsen, M.K., Singh, S.P., Solis, S., Sørensen, M., Tewari, A., Young, R. and Zahabu, E. 2011.
At the heart of REDD+: a role for local people in monitoring forests?
Conservation Letters 4: 158–167 (with cover page).

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Conservation Letters

A journal of the Society for Conservation Biology *Volume 4, Number 2, April/May 2011*

Community members measure the diameter of trees in a vegetation plot. Reduced Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+) is a new policy mechanism agreed under the United Nations Framework Convention on Climate Change. It aims to reduce carbon dioxide emissions from developing countries through the sustainable management of forests, while providing co-benefits of biodiversity conservation and livelihood support.
New findings by Finn Danielsen and his colleagues suggest that local people can collect forest condition data of comparable quality to trained scientists, at half the cost. REDD+ strategies that involve local community members in monitoring carbon stocks may improve the capacity of many developing countries to deliver large cuts in emissions at a low cost within a short time frame. It may be the only economic way for countries to gather data on changing rates of forest degradation, which would be needed if REDD+ credits are going to be claimed for reduced degradation as well as for deforestation. Empowering communities to own and monitor carbon stocks could also contribute to local livelihoods and forest biodiversity conservation. Photo by Eliakimu Zahabu.

LETTER

At the heart of REDD+: a role for local people in monitoring forests?

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Keywords
Climate change; co-benefits; community-based management; governance; locally based monitoring; forest degradation; REDD+.

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Received
30 August 2010
Accepted
24 November 2010

Editor
Michael Mascia

doi: 10.1111/j.1755-263X.2010.00159.x

Abstract

Reduced Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+) is a policy mechanism now agreed under the United Nations Framework Convention on Climate Change (UNFCCC). It aims to reduce carbon dioxide emissions from developing countries through the sustainable management of forests, while providing co-benefits of biodiversity conservation and livelihood support. Implementation challenges include linking remote sensing and national forest inventories of carbon stocks, to local implementation and measuring carbon loss from forest degradation. Community-based forest monitoring can help overcome some of these challenges. We show that local people can collect forest condition data of comparable quality to trained scientists, at half the cost. We draw on our experience to propose how and where local REDD+ monitoring can be established. Empowering communities to own and monitor carbon stocks could provide a rapid and cost-effective way of absorbing carbon dioxide emissions, while potentially contributing to local livelihoods and forest biodiversity conservation.

Introduction

At the 15th Conference of Parties of the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen, December 2009, an Accord was drafted proposing to stabilize global greenhouse gas concentrations in the atmosphere at a level that keeps global temperature increase below 2°C in the coming century (UNFCCC 2010a). The goal of the Copenhagen Accord can only be achieved if rates of deforestation and forest degradation in tropical developing countries are reduced as emissions from tropical forest destruction contribute approximately 17% of global greenhouse gas emissions annually (Barker *et al.* 2007). The use of economic

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instruments to provide positive incentives for reducing emissions forms the basis of the agreed UNFCCC policy "Reduced Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+)" (The Commission on Climate and Tropical Forests 2009; Clements 2010; UNFCCC 2010b). Payments would be linked to reducing emissions from the "reference emissions level"; for example through slowing rates of forest loss, reducing degradation, or enhancing forest carbon stocks (UNFCCC 2010c). REDD+ is an extension of the original REDD policy idea to include forest enhancement, sustainable forest management and conservation, as well as reduced deforestation and forest degradation. Although the REDD+ policy is aimed primarily at reduction of carbon emissions, it may also provide co-benefits (UNFCCC 2010c) in terms of biodiversity and livelihoods.

An operational REDD+ policy will require monitoring of deforestation and forest degradation across nations (Mollicone *et al.* 2007). This is not only to quantify the carbon savings in one area but also to account for potential increased loss of forest biomass ("carbon leakage") elsewhere within the same country. The requirement for forest monitoring has prompted an explosion of potential methodologies. The remote sensing community has proposed several ways to measure *deforestation* accurately and cheaply (e.g., Ramankutty *et al.* 2007; GOFC-GOLD 2009). Measuring forest *degradation* (loss of biomass within a forest) remotely is much more problematic. This presents a major challenge for implementing REDD+, since an important cause of carbon loss from forests in developing countries is a gradual degradation for example from extraction of timber, minerals, firewood, and charcoal by local communities or by people from other areas (The Nature Conservancy 2009; Ahrends *et al.* 2010). This diffuse degradation cannot be measured using traditional remote sensing methods (Achard *et al.* 2006; DeFries *et al.* 2007; Runk *et al.* 2010), although logging and more obvious degradation concentrated in space and time can usually be quantified particularly if measured shortly after the incident occurred (Souza *et al.* 2003, 2005). Alternative methods to measure degradation remotely, such as airborne light detection and ranging (LiDar), are now being developed (GOFC-GOLD 2009; Asner *et al.* 2010). An alternative way to measure standing carbon is ground inventory by professional foresters. This approach requires many trained personnel and is extremely expensive across whole nations (GOFC-GOLD 2009). It has been suggested that the huge technical, financial, and human capacity challenges involved in measuring degradation across whole countries or regions may render carbon credits for reversing degradation financially unviable (Lubowski 2008).

A potentially cheaper alternative monitoring approach at the local implementation scale of REDD+ is to engage local people in monitoring (Burgess *et al.* 2010; Phelps *et al.* 2010; Skutsch 2010). A locally based monitoring system could help make forest condition assessments economical across large areas of forest, and could be an important element in national REDD+ monitoring, reporting, and verification (MRV) systems. Permanence of emission reductions is also more likely if local communities are empowered than if they are alienated from the carbon stocks. Many community members have profound knowledge of the natural resources in their area (Berkes *et al.* 2000; Topp-Jørgensen *et al.* 2005). Results from well designed local monitoring schemes can be as reliable as those derived from professional monitoring (review in Danielsen *et al.* 2005). A locally based forest monitoring approach might therefore hold promise for REDD+. In this article, we assess data collected using monitoring approaches implemented by local people in three tropical developing countries against that collected by scientists. Our aim is to determine if locally collected data might be sufficiently accurate to measure degradation, and consequently carbon flux, for the purpose of REDD+. Comparative cost estimates of professional and locally based measurements of degradation are also provided to assess the relative costs of the two approaches. We also consider whether locally based forest monitoring would be likely to constitute empowerment of the local communities, or simply exploitation of cheap labor for the collection of data for a REDD+ program. Despite the paucity of data available for our analysis, we aim to provide preliminary quantitative assessments with which to inform discussion and stimulate further research.

Methods

To test how well community members can measure forest biomass and utilization, we compared results of community-based and professionally executed monitoring in India, Tanzania, and Madagascar. We chose study sites opportunistically (biomass measurements) and on the basis of existing locally based forest utilization monitoring schemes (forest utilization measurements). Representatives of the local communities in these areas helped us select community participants on the basis of their interest and experience with forest resources. Community members involved in measuring forest condition had only attended primary school, but received training from an intermediary organization, while the professional experts had academic degrees in the natural sciences.

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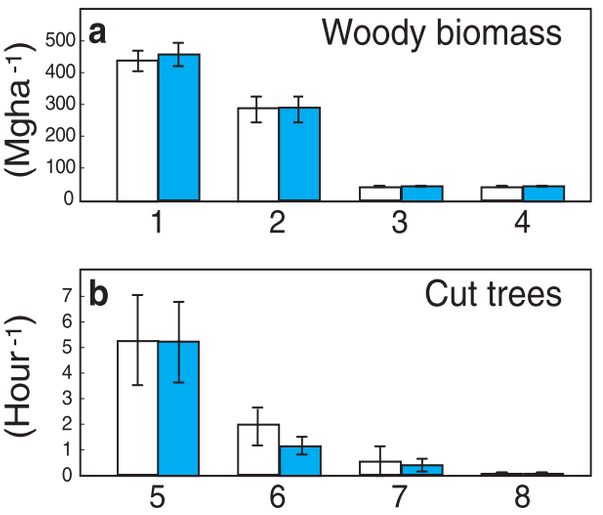

Figure 1 Comparison of forest condition data compiled by local people and trained scientists. Measurements of woody biomass (a, core sites 1–4) and cut trees (b, core sites 5–8) (± S.E.) by community members (white) and professional experts (blue) over a range of forest biomass and resource use intensities in dense oak forest (core site 1), oak forest (core site 2), and degraded forest (core site 3) in India, miombo woodland in Tanzania (core sites 4–6), and dry deciduous forest in Madagascar (core sites 7–8). Data from the other 11 study sites are provided in Table 2.

For forest biomass, we compared above ground biomass from three sites in India and one site in East Tanzania. For forest utilization, we compared five sites in the Eastern Arc Mountains of Tanzania and 10 sites in Madagascar.

From these 19 study sites, we chose a set of eight "core sites" for graphical presentation of the results (Figure 1). The core sites were selected so as to be representative of the full range of forest biomass and forest resource use intensities (Figure 1). For each type of measurement, we selected four core sites. For forest biomass this is all the measured sites. For forest utilization, it is two measured sites from each country. In Tanzania, there are one high-intensity, two medium-intensity, and two low-intensity sites in terms of forest utilization (Table 2b). We selected the high-intensity site (Itagutwa) and the best demarcated forest area among the two medium-intensity sites (Mfyome), where professional and community surveys were made in exactly the same areas (the alternative site, Ny'angoro, is part of a huge forest area where the forest resources are shared between six villages and each village's forest area is not clearly demarcated, see Appendix S3 footnote). In the study area in Madagascar, the intensity of forest utilization is minimal, and hence sites were randomly selected.

In the study sites in India (core sites 1–3), the vegetation is Himalayan temperate mountain forest at around 1,860 meters above sea level (m.a.s.l.), consisting of oak *Quercus* (Fagaceae) and pine *Pinus* (Pinaceae) forests in various states of utilization and degradation. Community members and scientists measured three different forest strata (defined as areas of homogeneous forest), one lightly used with dense oak and pine (40 ha; core site 1), one moderately used with even aged oaks (3 ha; core site 2), and one highly degraded area that had recently started to recover (15 ha; core site 3). In the forest biomass study site in East Tanzania (1,020 ha; core site 4), the vegetation is degraded miombo (*Brachystegia*) woodland at 250–400 m.a.s.l. The forest utilization sites in Tanzania comprised three sites (including core sites 5–6), where the vegetation is miombo woodland at 1,000–1,600 m.a.s.l. and two sites (Kidabaga and Lulanzi), where the vegetation is montane evergreen forest at 1,700–2,100 m.a.s.l. In the 10 forest utilization study sites in Madagascar (including core sites 7–8), the vegetation is dry, deciduous forest at 25–100 m.a.s.l (Appendix S1).

For the measurement of forest biomass (core sites 1–4), community members first identified forest strata with the assistance of an intermediate organization, after which community members and professional foresters independently carried out forest inventory in permanent plots based on methodology recommended by Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance (Penman *et al.* 2003; Table 1). For the measurement of forest utilization (15 sites including core sites 5–8), community members recorded the number of cut trees during regular patrols and we compared their results with results from scientists (Table 1). We adjusted the counts of cut trees for differences in effort by dividing the counts by the number of hours taken for the surveys in the relevant 3-month period (quarter) at the given site.

We estimated the cost of the community-based and professionally executed measurements on the basis of the actual expenses incurred during the training and fieldwork at each site (Appendix S2). Our cost estimates are conservative because study sites were fairly easy to reach by car. More remote areas would have been more expensive for experts to measure compared to communities.

We used *t*-tests (PROC *t*-tests, SAS 9.1; SAS Institute) for comparing the biomass per ha and the number of cut trees per hour recorded by community members and professional experts across sites. We used the same procedure to compare costs across approaches and sites. For biomass measurements, *n* refers to the number of permanent plots sampled by both types of monitors. For forest utilization measurements, *n* refers to the number of 3-month periods in which measurements were made by both types of monitors. Finally, to assess the ability of our study to detect statistically significant differences, we carried out a power analysis using the Sample Size

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Table 1 Description of the methods

Attribute measured	Training provided to the community members	Field survey protocol for community members and scientists	Data processing by community members	Timing and location of the data collection	Equipment	Definitions
Biomass	An intermediary organization trained community members in the use of a handheld computer in the field for: (i) entry of tree measurement data into a database; and (ii) use of the GPS functions to mark the boundaries of the forest strata and to locate the permanent plots. Teams of 3–7 community members were trained for 10 days in the first year. Refresher courses were provided in the 2nd and 3rd year.	The protocol comprised of: (i) Identification of forest strata by community members and the intermediary organization; distribution of sampling plots within each stratum. (ii) Independent inventory of forest vegetation plots by community members and scientists. In each plot, communities and scientists counted the trees, measured their dbh, measured the height of all trees >5cm dbh, and identified the species (MacDicken 1997; Penman *et al.* 2003; see Verplanke & Zahabu 2009).	Calculations were made directly in the computer as soon as measured data were inserted by the community members. The intermediary organization set up the database, uploaded a suitable base map into the computers initially, acquired and entered suitable allometric equations into the computers, and maintained the computers (batteries etc.).	In India, community members collected data every year for 7 years (2003 to 2009). In East Tanzania, community members collected data for 4 years (mid 2004–mid 2008). Scientists collected data only in 2008. We compared the results of the professional survey of forest biomass with community data from the same year. In India, the professional surveys used the same permanent plots as the community. In East Tanzania, the professionals set out new plots and, though they used the same number of plots, they increased the plot size.	Diameter tape, hypsometer, and handheld computer with (i) GPS functions; (ii) database with basemap and allometric equations.	By forest stratum, we mean a "homogenous forest area in terms of tree species composition and level of degradation." By dbh, we mean "diameter at breast height."
Cut trees	An intermediary organization trained community members in the recording of forest resources and resource use during forest patrols. Community members from each village were trained once for 2–3 days.	Community members recorded sightings of cut trees during patrols along regularly used paths through the forest, with patrols taking place 2–3 times every month and lasting 3 to 6 hours. Professional scientists recorded the number of cut trees along 1–2 transect routes of 2,000–2,500 m length located away from regular paths once every 3 months, and the speed of walking was kept constant at around 1km/ hour (250 m/15 minutes; by pacing).	In Tanzania, the community data were used largely unprocessed by the Village Natural Resource Councils for making decisions on natural resource management on a monthly basis (Topp-Jørgensen *et al.* 2005). In Madagascar, the community data were handed over to an intermediary organization who processed the data and who returned the results to the communities.	In Tanzania, communities collected data for 6 years (2002–2008); in Madagascar for 5 years (2004–2009). In Tanzania, scientists collected data from July 2007 to June 2008; and in Madagascar from January 2007 to June 2009. We compared the results of the professional survey of cut trees with community data from the same 3-month period. The community surveys were made along existing trails because the surveys were part of monitoring schemes not set-up for this study.	Notebook, pencil. The scientists also used a GPS receiver.	By cut tree, we mean a "cut tree bole, either the stump that remains or the cut bole itself."

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Application, distributed with SAS/STAT software (SAS 9.1, SAS Institute).

Results

We first tested for differences between local people's and scientists' forest biomass data. Over a range of forest biomass intensities from 450 to less than 50 Mgha^{-1} woody biomass—that is, dense oak forest (core site 1), oak forest (core site 2), and degraded forest (core site 3) in India, and miombo woodland in Tanzania (core site 4)—we found no significant differences in the estimates of mean above ground biomass made by community members and by professional foresters (Table 2a; Figure 1a). The local biomass estimates are reliable compared to professional estimates over a range of forest sites from high-carbon to low-carbon forest types. Our power analysis suggested that at least 35 permanent plots sampled by both types of monitors would be needed to obtain a probability of >80% to detect a difference of 20% with statistical significance. Only one site, Kitulangalo, met this criterion, and here there was clearly no significant difference ($P = 0.83$; $n = 89$; Table 2a).

We then compared the number of cut trees as recorded by community members and by scientists, which provides an estimate of rates of forest degradation and impact on carbon stock. Over a range of forest resource use intensities—from more than five to less than 0.1 cut trees per hour of census in heavily used miombo woodland in Tanzania (core site 5–6), montane evergreen forest in Tanzania, and dry deciduous forest in Madagascar (core site 7–8)—we found no significant difference in utilization estimates by community members and by scientists (P-values > 0.05; Table 2b; core sites shown in Figure 1b), although at two sites, the P-values were small ($P < 0.15$, i.e., Nyang'oro and Anketrevo; Table 2b). Our power analysis however suggested that at least 300 three-month periods sampled by both types of monitors would be needed to obtain a probability of >80% to detect a difference of 20% with statistical significance. None of our sites met this criterion (Table 2b). To account for the limited sample size at the site-level, we therefore aggregated the data on forest utilization from individual sites across all the measured sites in each country. Again, we did not find any significant difference between forest utilization measurements by community members and scientists (Tanzania, $P = 0.58$; $n = 19$; Madagascar, $P = 0.82$; $n = 80$). Moreover, the overall pooled mean utilization rates were almost identical (community members: 0.4967 per hour; scientists: 0.4845 per hour; $n = 99$).

Finally, we estimated the costs on a ha^{-1} basis of monitoring forest condition by local people and by experts. From an external perspective, the community measurements of above ground biomass annually cost USD 3.0–5.4 ha^{-1}, whereas expert-executed biomass measurements cost USD 10.3–11.1 ha^{-1} (Appendix S3; and the squares in Figure 2). Similarly, the community measurements of forest utilization annually cost USD 0.04–2.4 ha^{-1} (median USD 0.58 ha^{-1}), whereas expert-executed forest utilization measurements cost USD 0.62–12.37 ha^{-1} (median USD 1.2 ha^{-1}; Appendix S3; and the circles in Figure 2). Community measurements require more funds for training but there are much higher expenditures in expert-based measurements because of travel, field allowances, and salaries (Table 3). Across all 17 sites with financial data community measurements cost significantly less than expert-based measurements ($P = 0.038$; $n = 17$). The per hectare monitoring costs decreased significantly as forest size increased, both for community-based (Spearman Rank; $r_s = -0.91$; $n = 17$; $P < 0.0001$) and professional monitoring of forest condition ($r_s = -0.77$; $n = 17$; $P = 0.0003$; as illustrated in Figure 2).

Discussion

Our results are based on a limited data set but provide cautious support for the idea that in a number of developing country situations, and across a range of forest biomass and resource use intensities, local communities can measure forest biomass and utilization. Biomass data can be converted to estimates of stored carbon and with repeat surveys, the rate of change of stored carbon can be determined. The strongest agreement between community members and experts was for forest biomass, with lower agreement over forest utilization. This might be due to the low number of cut trees in some sites (e.g., Anketrevo; Table 2b) and because the community surveys of cut trees were made along existing trails, whereas scientists surveyed areas away from existing trails. In contrast, all biomass measurements were made in the same vegetation plots. Our results therefore support the idea that data collected by community members can meet the requirements of the highest reporting tier of the IPCC. This implies that community-based forest inventory data could be used for REDD+ applications, particularly for estimating changes in rates of degradation and forest enhancement (increased biomass stocks). Moreover, our findings suggest that community members can collect large volumes of data at relatively low cost.

There are a number of advantages of locally based monitoring for REDD+. One is that those communities, who live close to the forest, will be able to carry out repeated monitoring of data of relevance to REDD+, for

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Table 2 Results of the measurements of above ground biomass (a; $n = 125$ permanent plots) and forest utilization (b; $n = 99$ three-month periods) by local community members and professional experts in three countries

(a)

Country	Name of area (Core site number)	*n*	Professional survey of biomass Mean biomass in $Mgha^{-1}$ (S.E.)	Community survey of biomass Mean biomass in $Mgha^{-1}$ (S.E.)	*P*
India	Dhaili (1)	14	453.3 (36.7)	426.4 (36.6)	0.61
India	Dhaili (2)	15	283.4 (40.0)	279.9 (40.5)	0.95
India	Dhaili (3)	7	41.7 (4.6)	38.1 (4.7)	0.55
Tanzania	Kitulangalo (4)	89	43.2 (1.9)	42.2 (4.4)	0.83

(b)

			Professional survey of forest utilization			Community survey of forest utilization			
Country	Name of area (Core site number)	*n*	Hours of survey	Number of cut trees	Cut trees $hour^{-1}$, mean (S.E.)	Hours of survey	Number of cut trees	Cut trees $hour^{-1}$, mean (S.E.)	*P*
Tanzania	Itagutwa Village Forest (5)	4	36	186	5.19 (1.60)	63	255	5.3 (1.76)	0.97
Tanzania	Kidabaga	4	80	11	0.16 (0.09)	53	0	0 (0)	0.19
Tanzania	Lulanzi	4	34	3	0.11 (0.07)	96	0	0 (0)	0.19
Tanzania	Mfyome Village Forest (6)	4	38	47	1.14 (0.40)	112	169	1.95 (0.73)	0.37
Tanzania	Nyang'oro	3	52	62	1.60 (0.68)	93	323	3.63 (0.85)	0.14
Madagascar	Ampataka	7	14	5	0.39 (0.39)	131	0	0 (0)	0.36
Madagascar	Anketrevo	8	15	5	0.34 (0.14)	146	2	0.01 (0.01)	0.06
Madagascar	Ankoraobato	8	15	0	0 (0)	159	0	0 (0)	na
Madagascar	Kiboy	10	19	0	0 (0)	252	5	0.02 (0.02)	0.25
Madagascar	Kirindy Village (7)	6	11	4	0.36 (0.27)	110	55	0.60 (0.58)	0.71
Madagascar	Lambokely (8)	8	15	0	0 (0)	214	15	0.06 (0.05)	0.22
Madagascar	Mandroatsy	7	13	15	1.16 (0.81)	103	21	0.18 (0.09)	0.28
Madagascar	Marofandilia	8	14	1	0.07 (0.07)	169	17	0.09 (0.06)	0.80
Madagascar	Tsianaloky	10	18	0	0 (0)	210	0	0 (0)	na
Madagascar	Tsitakabasia	8	15	1	0.07 (0.07)	85	27	0.36 (0.36)	0.45

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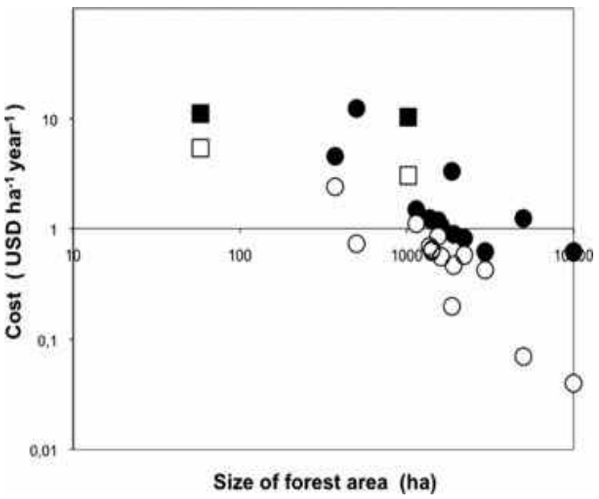

Figure 2 Comparison of the cost of monitoring the condition of forests by local people and trained scientists. Cost of measurements of woody biomass by community members (□) and professional experts (■) and of cut trees by community members (○) and professional experts (●) (log_{10} scales).

example annual measurements of biomass, which would be logistically impossible for professional surveys. Higher frequency of monitoring would greatly improve the statistical and scientific reliability of the results and the level of confidence in the results. Another advantage is that it could provide a fair basis on which communities could be paid for carbon savings, which in turn would provide an incentive for their engagement with REDD+ monitoring and forest management. This could be very good for forests and local livelihoods. Additionally, locally based monitoring provides a way to directly link monitoring to broader concepts of sustainable management of forests, including biodiversity conservation and livelihood support. It has been shown that the involvement of local communities in monitoring correlates with improvements in forest management (Gibson *et al.* 2005). In fact, just the presence of people may have a positive impact and deter illegal loggers. Moreover, involving local stakeholders in monitoring may increase the speed of decisions, and provide information to address environmental problems at operational scales of management (Danielsen *et al.* 2010). It may also enhance the capacity of local people to take care of their own local environment by increasing levels of local awareness and knowledge regarding the current status of the surrounding forest areas (Sheil & Lawrence 2004). A final advantage is that the locally based approach to monitoring may in fact be the best way to address some of the human rights issues that have been raised in connection with the implementation of REDD+ (Robledo *et al.* 2008). In developing countries about 240 million people live in tropical forests (Peskett *et al.* 2008), including some of the world's poorest and most marginalized communities who use the forest as their resource base (Funder 2009). At the UNFCCC negotiations, indigenous peoples' organizations have generally opposed REDD+ (IWGIA 2009; Rights and Resources 2010), mainly because it is expected to operate *via* national governments, and they fear it will undermine local control over forest resources and alienate communities from their resources (Chhatre & Agrawal 2009). In response to this, the current text on technical aspects of REDD+ explicitly allocates indigenous people and local communities a role in monitoring carbon stock change in forests (UNFCCC 2009).

There are also a number of potential disadvantages. One is that local communities will have a strong incentive to report positive trends in the forest cover and condition, so they continue to be paid, even if forests are actually declining. Periodic third party verification of the monitoring results will therefore be required, but this would need to be built into the design and costs of any REDD+ initiative, whether implemented by communities, the State, or the private sector. Independent verification could be based on random spot-checks or the use of high resolution remote sensing images. This would be unaffordable for national inventory, but would be appropriate for verification on

Table 3 Mean cost (over 4 years in USD) of community and expert-executed measurements of biomass and forest utilization across 17 sites with financial data (details in Appendix S3)

Attribute	Data gatherer	Training (S.E.)	Travel and accommodation (S.E.)	*Per* diem and food (S.E.)	Equipment (S.E.)	Salary and administration (S.E.)	Total cost (S.E.)	Total annual cost per ha* (S.E.)
		(USD)	(USD)	(USD)	(USD)	(USD)	(USD)	(USD/ha year)
Mean	Community	700 (97)	629 (227)	769 (108)	282 (59)	1,344 (333)	3,724 (651)	1.06 (0.33)
Mean	Professional	66 (14)	4,355 (1,133)	2992 (972)	61 (13)	6,507 (1,033)	13,982 (2,713)	3.33 (0.96)
P		1.0×10^{-4}	0.005	0.037	0.002	1.0×10^{-4}	0.002	0.038
n		17	17	17	17	17	17	17

* The total cost over 4 years divided with the size of the area and divided with 4 years.

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Table 4 Preliminary protocol to help decide where local REDD+ monitoring is appropriate (see also Ostrom 2009)

Who	Positive attributes
The local community	– Experience in communal management of natural resources – Evidence of trusted community organization and leadership – Residents show interest in sustainable forest management – Residents utilize forest resources – Clear rights over forest resources are present in practice
The government	– Government policy is in place for shared management of forest resources with communities – Community forest management has been adopted as a strategy within the national REDD+ program, and attendant procedures and rules are clear (e.g., on benefit distribution to directly affected communities, and verification) – National database for carbon stock accounts will accept data generated by communities at the local level
The intermediate organization	– Presence of suitable and interested intermediate organizations with experience of working with communities, within reasonable distance of the forests concerned
The forest area	– Minimum forest unit size of around 100 ha needed to break even on transaction costs of measurement – Evidence that community management will ensure tree growth and continued presence of the forest – No recent history of major conflicts, violence, or threats reported by forest managers or communities

Table 5 Three proposed steps in establishing a viable local REDD+ monitoring team

Step 1. Meet the leader of the community that is interested in carbon crediting. Explain the objectives and activities of local REDD+ monitoring. Stress the common interest of the government and local people in sustainable forest management.

Step 2. Assisted by the village leader, identify 10–15 community members among households utilizing the forest resources and persons involved in natural resource management (forest guards, community forestry committee members, etc.). Include the most experienced all-round forest product gatherers as well as some persons with literacy/numeracy. The persons should be permanent residents to ensure continuity as annual or bi-annual surveys are required (Verplanke & Zahabu 2009). Make sure that both men and women from different age groups are represented.

Step 3. From among these, a group of monitors of 5–8 people should be established based on a selection of the most willing and interested. This group should preferably remain the same over a long period of time. Together with the group and on the basis of a manual (e.g., Verplanke & Zahabu 2009), agree on what should be monitored, where and how.

the basis of sampling. It could be combined with statistical analysis of the community-based data to search for anomalies and growth rates that are beyond the normal or expected range.

Another disadvantage is that by engaging local communities in monitoring for REDD+ the State could be accused of offloading monitoring and reporting requirements, and their costs, onto poor local people. This indeed is a risk, although in reality a greater risk is that the State will apply for credits on the basis of improved management of the forests (as carried out now by the communities), bypassing them completely in terms of providing benefits. However, because remotely gathered data would be Tier 1 or at best Tier 2, the quantity of credits that the state could claim would be less than if local-level data (Tier 3) were available. It is thus in the interests of the State that greater accuracy is attained. The risk that local people might be intimidated by the State to exaggerate the carbon stock increases will be controlled by the requirement for third party independent verification.

To help address these challenges, we have developed a preliminary protocol to help decide whether the key conditions are in place for applying and sustaining local REDD+ monitoring (Table 4). This includes screening the potential risk posed to the locals from being involved in REDD+ monitoring. The protocol is intended for the preliminary planning and implementation of local REDD+ monitoring schemes and further work would be needed at the local level to verify and substantiate these variables on the ground.

Finally, it is clear that locally based monitoring is not a silver bullet. Not all local monitors are equally effective, and some are not able to tackle the task. A strong local REDD+ monitoring team requires a committed and competent group of community members, and the selection process to choose these people is critical. To aid this process, we propose three steps as described in Table 5. The competence of the community members also depends on the presence of an intermediary organization that would assist at the beginning in assessing the sample size required, laying out the permanent plots, as well as training.

In conclusion, REDD+ strategies that involve local community members in monitoring carbon stocks may significantly improve the capacity of many developing countries to deliver large cuts in emissions at a low cost within a short time frame. It may be the only economic

way for countries to gather data on changing rates of forest degradation, which would be needed if credits are going to be claimed for reduced degradation as well as for deforestation. Additionally, although REDD+ policy is primarily intended to reduce carbon emissions, a community-level approach will certainly involve holistic forest management, which would have the additional advantages of contributing toward conserving biodiversity within globally important forest types (Venter *et al.* 2009) and assisting in the support of local livelihoods (Chhatre & Agrawal 2009). If locally based forest monitoring is to become a key element of the MRV of REDD+ schemes, further quantitative assessments of the ability of locally based forest monitoring methods to detect changes in forest condition are needed. It should also be explored to what extent community members can monitor other aspects of central importance to REDD+ implementation like governance, livelihoods, and biodiversity.

Acknowledgments

We thank the approximately 120 community members at the study sites for sharing with us their measurements of forest condition and we thank Netherlands Development Cooperation and Danida for financial support. A. Chhatre, M. Enghoff, M. Funder, M. McCall, and six anonymous reviewers provided comments on a draft.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1: Study areas.

Appendix S2: Details of how the costs of community and scientist-collected forest condition data were calculated.

Appendix S3: Cost (over 4 years in USD) of community and expert-executed measurements of biomass and forest utilization.

Blomley, T., Ramadhani H. (2006) Going to scale with participatory forest management: early lessons from Tanzania. *Int For Rev* **8**, 93–100.

Somanathan, E., Prabhakar R., Mehta B.S. (2009) Decentralization for cost-effective conservation. *Proc Natl Acad Sci USA* **106**, 4143–4147.

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References

Achard, F., Belward A.S., Eva H.D. *et al*. (2006) *Accounting for avoided conversion of intact and non-intact forest: technical options and a proposal for a policy tool*. European Commission Joint Research Centre, Brussels.

Ahrends, A., Burgess N.D., Milledge S.A.H. *et al*. (2010) Predictable waves of sequential forest degradation and biodiversity loss spreading from an African city. *Proc Natl Acad Sci USA* **107**, 14556–14561..

Asner, G.P., Powell G.V.N., Mascaro J. *et al*. (2010) High-resolution forest carbon stocks and emissions in the Amazon. *Proc Natl Acad Sci USA* **107**, 16738–16742.

Barker, T., Bashmakov I., Bernstein L. *et al*. (2007) Technical summary. In B. Metz, O.R. Davidson, P.R. Bosch, R. Dave & L.A. Meyer, editors. *Climate change 2007: Mitigation Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, New York.

Berkes, F., Colding J., Folke C. (2000) Rediscovery of traditional ecological knowledge as adaptive management. *Ecol Appl* **10**, 1251–1262.

Burgess, N.D., Bahane B., Clairs T. *et al*. (2010) Getting ready for REDD +in Tanzania: a case study of progress and challenges. *Oryx* **44**, 339–351.

Chhatre, A., Agrawal A. (2009) Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. *Proc Natl Acad Sci USA* **106**, 17667–17670.

Clements T. (2010) Reduced expectations: the political and institutional challenges of REDD+. *Oryx* **44**, 309–310.

Danielsen, F., Burgess N.D., Balmford, A. (2005). Monitoring matters: examining the potential of locally-based approaches. *Biodiv Conserv* **14**, 2507–2542. Available from: www.monitoringmatters.org. Accessed 15 November 2010.

Danielsen, F., Burgess N.D., Jensen P.M., Pirhofer-Walzl K. (2010) Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples involvement. *J Appl Ecol*, **47**, 1166–1168.

DeFries, R., Achard F., Brown M. *et al*. (2007) Earth observations for estimating greenhouse gas emissions from deforestation in developing countries. *Environ Sci Policy* **10**, 385–394.

Funder, M. (2009) *Reducing emissions from deforestation and degradation: an overview of risks and opportunities for the poor*. *Technical Report* 2009-21. Danish Institute for International Studies, Copenhagen.

Gibson, C.C., Williams J.T., Ostrom E. (2005) Local enforcement and better forests. *World Dev* **33**, 273–284.

GOFC-GOLD. (2009) A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses in carbon stocks in forests remaining forests, and forestation. Ed. COP15-1. GOFC-GOLD, Alberta, Canada.

 Copyright and Photocopying: ©2011 Wiley Periodicals, Inc.

IWGIA. (2009) *Indigenous affairs: REDD and indigenous peoples*. International Working Group on Indigenous Affairs, Copenhagen.

Lubowski, R. (2008) What are the costs and potentials of REDD? Pages 23–30 in A. Angelsen, editor. *Moving ahead with REDD: issues, options and implications*. CIFOR, Bogor, Indonesia.

MacDicken, K. (1997) *A guide to monitoring carbon storage in forestry and agroforestry projects*. Winrock International Institute for Agricultural Development, Arlington, Virginia.

Mollicone, D., Freibauer A., Schulze E.D. *et al*. (2007) Elements for the expected mechanisms on 'reduced emissions from deforestation and degradation, REDD' under UNFCCC. *Environ Res Lett* **2**, 045024. doi:10.1088/1748-9326/2/4/045024.

Ostrom, E. (2009) A general framework for analyzing sustainability of social-ecological systems. *Science* **325**, 419–422.

Penman, J., Gytarsky M., Hiraishi T. *et al*., editors. (2003) *Good practice guidance for land use, land use change and forestry*. IPCC, Institute for Global Environmental Strategies, Kanagawa, Japan.

Peskett, L., Huberman D., Bowen-Jones E., Edwards G., Brown J. (2008) *Making REDD work for the Poor*. Poverty & Environment Partnership, Overseas Development Institute, London.

Phelps, J., Webb E.L., Agrawal A. (2010) Does REDD+ threaten to recentralize forest governance? *Science* **328**, 312–313.

Ramankutty, N., Gibbs H.K., Achard F. *et al*. (2007) Challenges to estimating carbon emissions from tropical deforestation. *Glob. Change Biol* **13**, 51–66.

Rights and Resources. (2010) *The end of the hinterland forests, conflict and climate change*. Rights and Resources Initiative, Centre for People and Forests, Forest Peoples Programme, World Agroforestry Centre, Nairobi.

Robledo, C., Blaser J., Byrne S., Schmidt K. (2008) *Climate change and governance in the forest sector*. Rights and Resources Initiative, Washington, DC.

Runk, J.V., Negría G.O., Conquista L.P. *et al*. (2010) Landscapes, legibility, and conservation planning: multiple representations of forest use in Panama. *Conserv Lett* **3**, 167–176.

Sheil, D., Lawrence A. (2004) Tropical biologists, local people and conservation: new opportunities for collaboration. *Trends Ecol Evol* **19**, 634–638.

Skutsch, M., editor. (2010) *Community forest monitoring for the carbon market: opportunities under REDD*. Earthscan, London.

Souza, C. Jr., Firestone L., Silva L.M., Roberts D. (2003) Mapping forest degradation in the Eastern Amazon from SPOT 4 through spectral mixture models. *Remote Sens Environ* **87**, 494–506.

Souza, C., Roberts D.A., Cochrane M.A. (2005) Combining spectral and spatial information to map canopy damage from selective logging and forest fires. *Remote Sens Environ* **98**, 329–343.

The Commission on Climate and Tropical Forests. (2009) *Protecting the climate forests*. Available from: http://www.climateforestscommission.org/the-report/. Accessed 20 June 2010.

The Nature Conservancy. (2009) *Don't forget the second D; the importance of including degradation in a REDD mechanism*. The Nature Conservancy, Arlington, Virginia.

Topp-Jørgensen, E., Poulsen M.K., Lund J.F., Massao J.F. (2005) Community-based monitoring of natural resource use and forest quality in montane forests and miombo woodlands of Tanzania. *Biodiv Conserv* **14**, 2653–2677.

UNFCCC. (2009) *FCCC/SBSTA/2009/L.9 10 June 2009, SBSTA, 13th session, Bonn, 1.10 June 2009, Agenda item 5, Reducing emissions from deforestation in developing countries: approaches to stimulate action*. UNFCCC, Bonn, Germany.

UNFCCC. (2010a) *Decision 2/CP.15, Copenhagen Accord*. UNFCCC, Bonn, Germany. Available from: http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf#page=11. Accessed 28 August 2010.

UNFCCC. (2010b) *Draft decision–/CP.16, Outcome of the work of the ad hoc working group on long-term cooperative action under the convention*. UNFCCC, Bonn, Germany. Available from: http://unfccc.int/files/meetings/cop_16/application/pdf/cop16_lca.pdf. Accessed 16 December 2010.

UNFCCC. (2010c) *Decision 4/CP.15, Methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forest and enhancement of forest carbon stocks in developing countries*. UNFCCC, Bonn, Germany. Available from: http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf#page=11. Accessed 28 August 2010.

Venter, O., Laurance W.F., Iwamura T. *et al*. (2009) Harnessing carbon payments to protect biodiversity. *Science* **326**, 1368.

Verplanke, J., Zahabu E. (2009) *A field guide for assessing and monitoring reduced forest degradation and carbon sequestration by local communities*. KTGAL Project, Enschede, The Netherlands.

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APPENDIX XII

Skutsch, M., Zahabu, E., Karky, B.S. and **Danielsen, F.** 2011. The costs and reliability of forest carbon monitoring by communities. Pg. 73–81 in: *Community Forest Monitoring for the Carbon Market* (Ed. M. Skutsch). Earthscan, London.

6
The Costs and Reliability of Forest Carbon Monitoring by Communities

Margaret Skutsch, Eliakimu Zahabu, Bhaskar S. Karky and Finn Danielsen

Introduction

This chapter primarily addresses the costs of forest monitoring for carbon stock changes, as carried out by local communities in ground-level inventories. The question we ultimately seek to answer is whether community monitoring of carbon stock changes is cost-effective, taking into account the costs of training and the subsequent monitoring by communities with limited supervision. It is of course necessary also to evaluate whether the results of such community-based surveys are reliable, and this we test by statistical comparison between the results of community inventories and those of professional foresters and scientists at the same sites. The chapter concludes by describing other advantages of community monitoring, which may have profound implications for the long-term sustainability and cost-effectiveness of national REDD+ programmes.

Cost components of community carbon forestry

Forest monitoring is one of the major costs that will be incurred in national REDD+ programmes, and if communities are involved in REDD+ through some form of community forest management, the possibility arises that they could do the measurement and monitoring themselves. Besides the monitoring costs, there are many others associated with community carbon forestry, including the set-up and general management costs of community forest management (CFM) initiatives, and the opportunity costs that the local people face in choosing to manage the forest sustainably, rather than convert the land for other uses or overexploit the resources available. These costs are not dealt with in this chapter, although they are considered in some of the case studies (Chapters 9 and 11). There is also a set of administration and transaction costs

which will be incurred outside the community if carbon credits are to be marketed through a national REDD+ system. These include costs of registration and validation of the community's right to participate in the national REDD+ programme, which might, for example, include checks on land tenure and some control on how the community is institutionalizing the management of forest and handling the finance, as there may be concerns about the legitimacy of inclusion and exclusion and benefit sharing among households. There will also be external transaction costs related to reporting and verification (checking the data for errors and falsification); and finally there will be administration costs associated with running the national payment system, as well as general costs to cover all the ancillary activities that have to be carried out at national level, such as constructing the reference emission level, setting up and maintaining the national database, and dissemination of information about REDD.

There is very little experience of estimating these kinds of costs at the moment (Corbera et al, 2010), since the costs involved in management of national REDD programmes are likely to be somewhat different from costs associated with the few individual REDD-type projects which have been implemented up to now. It is probable, however, that all these costs taken together will be considerable, and that the remuneration to the community for the carbon saved will constitute only a fraction of the international market value of the carbon. This is of course a common feature of global commodity chains, and we cannot realistically expect that the proportion of the retail price that the producers receive will be much higher for carbon than, say, for roses exported to Europe from Kenya, or clothing from workshops in China. Nevertheless, it is important to have some idea of what the real 'production costs' of carbon are, from the point of view of the community.

From the point of view of the government, the question of whether community monitoring of forest carbon stocks is cost-effective cannot really be answered without reference to all these other costs. Moreover, it is clear that from the community's point of view, it would only be worth spending time monitoring carbon stock changes if the overall benefits of participation in REDD+ outweigh the overall costs. These are complex calculations involving a number of unknown values, and it will be some time before practical experience generates information on them. However, it is possible at this stage to compare the costs of community inventories with those of inventories carried out by professional foresters, and this important comparison is made in this chapter.

Costs of community carbon inventories

The cost of undertaking community carbon inventories comprises a number of different costs. Firstly, the training, in which cost of community members' time, and costs of the training or intermediary agency, would be included. The process of making the inventory itself could be considered to consist of a number of different steps, which include mapping the forest area if geo-referenced maps are not already available, mapping the different forest strata (vegetation types and levels of degradation), setting out the permanent sampling plots,

measuring the trees and taking samples of shrubs and soil, if these are to be included, recording the data electronically, if not done already during measurements in the field, and carrying out the analysis of the data (see Chapter 3 for a more elaborate presentation of these steps). There are costs associated with the supervision provided by the intermediary institution for some of these tasks (including time and travel costs), and there are costs for equipment. Some of the costs are one-off, as they are required only in the first year (mapping and setting out of permanent plots). Others, like the work of measuring trees and data recording, may hardly vary from year to year, or slowly decrease. Training is a high cost in the first year, but refresher training may be required for a number of subsequent years, though the costs of this should decrease over time as communities become more familiar with the procedures involved. The costs of the intermediary/training organization will depend heavily on the distance its staff members have to travel, so that more isolated communities are likely to incur higher costs in this regard.

It is clear that the overall costs would be expected to fall over time, and that estimates should therefore be made on the basis of an average over a number of years. In addition, it may be expected that costs will reflect economies of scale, since the sampling requirements will be relatively smaller in larger areas of forest. Training costs will be independent of forest size, and will therefore fall proportionately more heavily on villages with smaller forest areas.

This is illustrated by the cases of some of the K:TGAL sites in Nepal, Tanzania and India (Tables 6.1–6.3), for which data on costs were gathered. The costs incurred by the villages are based on the number of days work involved including the training, at normal local rates of pay, but it was not possible to assess the time taken for the different tasks, as only the total days for training and for survey work were recorded. The data on costs to the support organization for intermediary services and training are not entirely comparable between the sites, as they were estimated in different ways in the different countries. A large part of these costs is for travel and subsistence of staff of these organizations, which can be very high for the case of isolated settlements such as Manang in Nepal. To reach Manang, staff of the support organization had to travel for several days.

The costs presented in the tables do not include the equipment costs, particularly the cost of the handheld computers that were used in these exercises. A set as described in Chapter 7 includes a handheld computer or personal digital assistant (PDA) at around US$500, and standard Geographical Information Systems (GIS) software which also costs around US$500. These would be one-off costs. In most villages a set would be needed for less than a week every year; the hardware might have a lifetime of two years, while the GIS might be amortized over five years. Assuming the set were to be lent by the support organization to 20 villages per year, each with an average of 100ha of forest, the cost per hectare per year would be less than US$0.20, not considering other uses to which the equipment might be put to in addition to its use in forest inventory work. For example, in a village in Tanzania in which we worked, the villagers also used the GIS system to map their village boundaries. They had been waiting for many years in vain for the Survey Department

to come and do this for them. With more advanced equipment as described in Chapter 8, with free software and Smartphones, the costs would be considerably less, and the additional possible uses of the equipment would be greater (e.g. the telephone services it offers). The Smartphone is also equipped with camera and video facilities.

In the analysis that follows, costs are estimated both per hectare of forest and per tonne of CO_2. It should be noted, however, that in these calculations, only the forest enhancement component has been included. If there are grounds (and sufficient data) for accounting also for avoided degradation in the forests, then the monitoring costs per tonne would be proportionately lower.

The findings in the tables demonstrate four important points. Firstly, they show that the average costs per hectare of community monitoring of biomass in tropical forests are highly variable. In the examples presented, they range from US$2.50 to US$5.50 per hectare per year; for Papua New Guinea, total costs were reported as US$3.85 per hectare, which is also within this range (estimates were not made for the other countries in the study). Costs per tonne of CO_2 vary from US$0.20 to US$2.50. Secondly, the findings show that the costs decrease over time. There are high start-up costs associated with training and with setting up the permanent sampling plots, but as the communities

Table 6.1 *Cost of community-based forest inventory, Nepal (in US$)*

Nepal, 3 villages	*1st year*	*2nd year*	*3rd year*	*Average cost over 3 years*	*Average annual cost per ha*	*Average annual cost per tonne CO_2 (1)*
Costs to the community						
Training costs						
Ilam (383ha)	112.0	77.0	77.0	88.6		
Lamatar (96ha)	88.0	80.0	0.0	56.0		
Manang (240ha)	65.0	n/a (2)	29.0	47.0		
Survey costs						
Ilam	282.0	247.0	193.0	240.6		
Lamatar	301.0	267.0	247.0	271.6		
Manang	265.0	n/a	174.0	219.5		
Costs to support organization						
Ilam	695.0	621.0	391.0	569.0		
Lamatar	374.0	0.0	0.0	124.6		
Manang	1135.0	n/a	775.0	955.0		
Total costs						
Ilam	1089.0	945.0	661.0	898.0	2.4	0.2
Lamatar	763.0	347.0	247.0	452.0	4.7	1.5
Manang	1465.0	n/a	978.0	1222.0	5.1	2.5

(1) CO_2 yield: Ilam 11t/ha/year (provisional estimate), Lamatar 3.1. Manang lost carbon stock due to a single (illegal) deforestation event in 2006, giving it an overall loss during the period studied. However, as shown in Chapter 2, the long-run trend in biomass growth is positive (±2t/ha/year). This estimate has been applied here.
(2) Data were not collected in Manang in year 2 because of heavy snowfall.

Table 6.2 *Cost of community-based forest inventory, Tanzania (US$)*

Tanzania, Gwata village (1020ha)	*1st year*	*2nd year*	*3rd year*	*4th year*	*Average cost over 4 years*	*Average annual cost per ha*	*Average annual cost per tonne CO_2 at 1.3t/ha (1)*
Costs to the community							
Training costs	350.0	175.0	90.0	0.0	205.0		
Survey costs	735.0	595.0	450.0	600.0	595.0		
Costs to support organization	4340.0	2570.0	1820.0	690.0	2355.0		
Sum of costs	5425.0	3340.0	2360.0	1290.0	3079.0	3.1	2.3

(1) CO_2 yield based on weighted average of the two parcels managed by Gwata in the Kitulungalo area: the forests of Kimunyu and Sokoine University of Agriculture Training Forest (SUATF).

Table 6.3 *Cost of community-based forest inventory, India (US$)*

India, Dhaili (58ha)	*1st year*	*2nd year*	*3rd year*	*4th year*	*Average cost over 4 years*	*Average annual cost per ha*	*Average annual cost per tonne at 6.53t/ha*
Costs to the community							
Training costs	136.0	136.0	136.0	0.0	102.0		
Survey costs	340.0	170.0	170.0	170.0	212.5		
Costs to support organization are included in survey costs							
Sum	476.0	306.0	306.0	170.0	314.5	5.4	0.8

become more proficient in tree measuring from year to year, they require less supervision. Thirdly, the data confirm the fact that economies of scale are of very significant influence. Zahabu and Malimbwi (2008) estimated that the costs of community monitoring of biomass would be less than US$2 per hectare in forests with areas of more than 150ha in Tanzanian miombo woodlands, because relatively fewer samples are needed per hectare in these larger forests and because training has a fixed cost regardless of forest size. Fourthly, it is clear from the three case studies that the costs of the supporting agency form a considerable part of the total. Part of this cost is inevitable: training and supervision are essential initially. But the location of the community is of considerable importance. Manang, in the high mountains of Nepal, is a good example: the costs of the support agency included flights to the area as well as their time. Obviously, such high costs can hardly be expected to be borne by the returns on the carbon.

Our findings suggest that governments may have to be selective in admitting communities into a national REDD+ programme, for three reasons. Firstly, it will be uneconomic to include very small forest areas as individual units, as the costs of monitoring outweigh the probable market value of the carbon credits generated. The communities themselves would lose out. The only way they could participate profitably would be if several such (adjacent) villages combined efforts and submitted the registration of their forests to the national REDD+ programme as a single entity. This would mean that the carbon gains, credits and payments would have to be averaged out over the whole area. Sharing would require considerable trust and cooperation between the different villages managing the forests, which are not necessarily present. Because of differences in management effectiveness and yields at the local level, there would be many potential sources of conflict. Overcoming such difficulties could be a major challenge for national REDD+ programmes.

Secondly, if villages are very isolated and not within the reach of suitable support organizations, the costs per tonne of CO_2 may not be covered by the value of the credits. Hence it may be necessary for governments to focus on those community forest management groups which are more accessible. This has considerable implications for equity and legitimacy, and also needs to be carefully considered in the design of national REDD+ payment mechanisms.

Moreover, in terms of costs per tonne, it is obvious that sites in which growth is faster will have much lower average costs. Hence the temperate forest sites in India, which have the highest per hectare costs, have the lowest per tonne CO_2 costs. From the point of view of efficiency, a national REDD+ programme might, therefore, have to consider focusing on those degraded forests with the greatest potential for rapid growth, leaving aside those whose natural conditions allow increments of only a few tonnes per hectare per year. This too would have implications for political acceptability of the programme.

Comparative cost of professional inventories

Independent professional inventories were carried out in two of the sites presented above, primarily to check the reliability of the communities' data (Kitulangalo, Tanzania and Dhaili in Uttarakhand, in India). This, however,

presented an opportunity to compare costs. Experts costs in Kitulangalo (for Kimunyu village forest reserve and Sokoine University of Agriculture Training Forest (SUATF)) came to US$10 per hectare, while they were US$11 in Dhaili, indicating that community-based surveys, including costs of the support agencies and all the training involved, can be carried out for around 30–50 per cent of the cost of professional surveys in the long run.

This is of considerable significance for the design of national REDD+ programmes. In areas which are being protected primarily from degradation (as in most community forest management schemes), there are annual increases in carbon stock, but these are not enormous, and ground level measurements are essential for establishing their magnitude. In crediting the gains, transaction costs will have to be kept as low as possible, as the financial margins will be narrow. Our findings demonstrate that community monitoring offers an attractive opportunity in this regard.

Reliability of community surveys

Comparison of the results of the independent inventories and community measurements in Kitulangalo and Dhaili indicate that local biomass estimates are as reliable as those of professionals; or rather, that the results are not significantly different (Danielsen et al, 2010). Both the professional and the community teams measured diameter at breast height and height of trees, identified the species, and applied the relevant allometric equations to reach the estimate of above-ground woody biomass given in the table. Statistically, there are no significant differences in the estimates of mean biomass made by community members and by professional foresters (Table 6.4). The reason for the lower standard error for the case of expert measurement in Kitulangalo is because the experts decided to increase the sample plot size. This increased the precision of their measurement (i.e. reduced the width of the confidence interval), but not the accuracy. It is not clear what levels of precision would be required from biomass measurements in REDD, and there will be a trade-off to be considered in terms of the extra time and cost involved in surveys to

Table 6.4 *Comparison of results of professional and community surveys*

Country	*Type of forest*	*No of plots*	*Statistic*	*Professional survey Biomass (t/ha)*	*Community survey Biomass (t/ha)*	*P*
India, Dhaili	Stratum 1: even-aged oak forest	14	Mean SE	453.3 36.7	426.4 36.6	0.61
India, Dhaili	Stratum 2: dense oak forest	15	Mean SE	283.4 40	279.9 40.5	0.95
India, Dhaili	Stratum 3: degraded oak	7	Mean SE	41.7 4.6	38.1 3.7	0.55
Tanzania, Kitulangalo	Savanna woodland (miombo)	89	Mean SE	43.2 1.9	42.2 4.4	0.83

deliver lower standard errors (see also Chapter 5). The use of more strata is another way to reduce standard error and increase precision.

In this regard, the ability of communities to stratify their forests for statistical analysis was observed to be questionable in some cases. We noted that villagers tended to stratify on the basis of predominant tree species present. However, level of degradation may be an even more important factor distinguishing biomass levels, and hence in increasing the precision of the estimates. This may be one of the steps in the process in which more guidance by the support agency is required. In the Dhaili site in India, for example, the community received help in this matter from the support organization. Had they sampled their forest without using the strata as shown in Table 6.4, the levels of precision would have been much lower.

There were also occasional incidences observed, in which community measurements were not reliable. These were, however, mostly corrected during the first two years by the support organization. In Ilam in Nepal, an error arose as a result of the communities not fully understanding how to operate the GPS equipment when working on their own. As a result, the samples were taken not from the same permanent plots every year, but from different plots. Scanning of the data in time series easily reveals this kind of mistake as data are inconsistent between years. This indicates the importance of having a local agency to supervise, pick up on errors early and explain to the community what the problem is. Overall, however, such data faults were found to be rare.

In conclusion, our analysis suggests that local people are capable of collecting data that are sufficiently reliable to monitor growth of carbon within their forests, and to justify claims for carbon credits within a national REDD system or even directly in an international carbon market. Our sample, however, was small, and further rigorous verification studies would be needed in other sites to fully assess the reliability of community monitoring of biomass.

Implications for national REDD+ programmes

The limited data that our study provided indicate that local communities can monitor forest biomass to a level that is in no way inferior or less reliable than that of professional foresters, and that the data generated are adequate for the purposes of REDD+. Our findings also suggest that community members can collect large volumes of forest biomass data at relatively low cost (Danielsen et al, 2010). One advantage of this is that communities would be able to carry out repeated monitoring; for example, taking biomass measurements on an annual basis. This greatly increases the reliability of results from a scientific point of view, as it involves repetition of measurement of variables, thus providing greater confidence in the results, as well as the possibility to scan the data regularly for anomalies. Trends should be easy to establish, and any perturbations in these trends would be visible, enabling errors to be traced. Annual monitoring will also ensure that the communities' skills in inventory work do not get forgotten.

Another advantage of this approach is that monitoring could be carried out simultaneously and at reduced cost across all areas of forest which are

under some form of community management, greatly increasing the geographical extent over which REDD+ may be technically possible and financially viable. Whereas it takes a student at least three years to become a professional forester, community members can monitor forest condition after only a few days of training, greatly accelerating the speed of potential REDD+ implementation on the ground. Adjustment of REDD+ strategies, so they involve community members in monitoring carbon stock change, could dramatically improve the capacity of many developing countries to deliver cuts in emissions at a relatively low cost within a short time. It would enable them to place large areas of forest which are not at threat from deforestation, but which are steadily degrading and emitting carbon dioxide, under REDD+, and thus benefit from international carbon funds or the international carbon market. Moreover, there is evidence that communities that include forest monitoring in their management practices tend to manage their forest better, perhaps because of the increased level of information which they have at their own disposal (Gibson et al, 2005; Ostrom, 2009).

Last, but certainly not least, quantitative monitoring of their forest stocks would give local communities a legitimate basis for claiming compensation for positive changes in carbon stock. Such a system promotes transparency and accountability, and could be a cornerstone on which to create an equitable governance system and a fair basis for the distribution of financial rewards under national REDD+ programmes. In this way, it could at the same time contribute to reducing poverty and sustainable development, other important goals of a REDD+ mechanism.

References

Danielsen, F., Skutsch, M., Burgess, N.D., Jensen, P.M., Andrianandrasana, H., Karky, B., Lewis, R., Lovett, J., Massao, J., Ngaga, Y., Phartiyal, P., Poulsen, M.K., Singh, S.P., Solis, S., Tewari, A., Young, R. and Zahabu, E. (2010) 'At the heart of REDD: A role for local people in monitoring forests?', Submitted to *Conservation Letters*, August 2010

Gibson, C.C., Williams, J.T., and Ostrom, E. (2005) 'Local enforcement and better forests', *World Development*, vol 33, pp273–284

Ostrom, E. (2009) Plenary Speech: Forest Day, Copenhagen, 13 December, http://www.cifor.cgiar.org/publications/pdf_files/cop/cop15/Ostrom-speech.pdf

Zahabu, E. and Malimbwi, R. (2008) 'Participatory forest inventory: a solution to forest data scarcity in Tanzania', *Proceedings of the Mpingo Workshop*, November 2008, Morogoro, Tanzania

ERRATA: (1) Table 6.1. Footnote: Lamatar 3.1, the unit is t/ha/year. (2) Table 6.2. Training costs; 205 should be 153.8. Sum of costs; 3079 should be 3103.8. Footnote; "Kitulungalo" should be "Kitulangalo". (3) Table 6.4. India, Dhaili, stratum 3, community survey, SE: 3.7 should be 4.7. (4) Reference list, add Corbera, E. et al. 2010. Clim. Change 100: 355-388. (5) The publishing year of Danielsen et al. is 2011.

APPENDIX XIII

Danielsen, F., Adrian, T., Brofeldt, S., Noordwijk, M. van, Poulsen, M.K, Rahayu, S., Rutishauser, E., Theilade, I., Widayati, A., An, N.T., Bang, T.N., Budiman, A., Enghoff, M., Jensen, A.E., Kurniawan, Y., Li, Q., Mingxu, Z., Schmidt-Vogt, D., Prixa, S., Thoumtone, V., Warta, Z. and Burgess, N. 2013.
Community monitoring for REDD+: international promises and field realities.
Ecology and Society 18(3):41.

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Danielsen, F., T. Adrian, S. Brofeldt, M. van Noordwijk, M. K. Poulsen, S. Rahayu, E. Rutishauser, I. Theilade, A. Widayati, N. The An, T. Nguyen Bang, A. Budiman, M. Enghoff, A. E. Jensen, Y. Kurniawan, Q. Li, Z. Mingxu, D. Schmidt-Vogt, S. Prixa, V. Thoumtone, Z. Warta, and N. Burgess. 2013. Community monitoring for REDD+: international promises and field realities. Ecology and Society **18**(3): 41. http://dx.doi.org/10.5751/ES-05464-180341

Research, part of a Special Feature on Beyond Carbon: Enabling Justice and Equity in REDD+ Across Levels of Governance

Community Monitoring for REDD+: International Promises and Field Realities

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ABSTRACT. Will community monitoring assist in delivering just and equitable REDD+? We assessed whether local communities can effectively estimate carbon stocks in some of the world's most carbon rich forests, using simple field protocols, and we reviewed whether community monitoring exists in current REDD+ pilots. We obtained similar results for forest carbon when measured by communities and professional foresters in 289 vegetation plots in Southeast Asia. Most REDD+ monitoring schemes, however, contain no community involvement. To close the gulf between United Nations Framework Convention on Climate Change texts on involving communities and field implementation realities, we propose greater embedding of community monitoring within national REDD+ pilot schemes, which we argue will lead to a more just REDD+.

Key Words: biodiversity; Climate, Community and Biodiversity Alliance standard; forest carbon; governance; livelihood; monitoring; Payment for Ecosystem Service programs; REDD+; Southeast Asia

INTRODUCTION

Efforts to reduce greenhouse gas emissions from deforestation and forest degradation (core elements of Reduced Emissions from Deforestation and Degradation [REDD+]) require the convergence of (1) international rules, finance, and investment; (2) national accountability for future emission levels compared with current ones; and (3) local changes in incentives and behavior that involve the major external and local drivers of change in tropical forest margins (Ghazoul et al. 2010, Angelsen et al. 2011).

Current United Nations Framework Convention on Climate Change (UNFCCC) texts and guidance documents on the technical aspects of REDD+ outline explicit roles for indigenous people and local communities in implementing REDD+ (GOFC-GOLD 2010, Epple et al. 2011, UNFCCC 2011a, b), and state that projects should secure Free Prior and Informed Consent before implementation begins (UN-REDD 2011, FPP 2012). However, it has been questioned whether these good intentions are being translated into activities on the ground in countries where pilot projects are testing modalities for implementing REDD+ (Angelsen et al. 2009, Howell 2012).

In recent years, a broad literature has been generated on the many methods that can be employed to measure forest carbon at the scale of the nation state or subregional areas within a nation (e.g., Asner et al. 2010, GOFC-GOLD 2010). Typically, these involve a combination of remote sensing (with many options available) and plot-based carbon measurements carried out by professional foresters (with many ways of doing this work), in combination with data on wood density, and various conversion factors to convert tree measurements in the field to biomass carbon. Less often, these procedures also include other Intergovernmental Panel on Climate Change (IPCC) carbon pools (deadwood, roots, soil carbon), and considerations of REDD+ safeguards, such as biodiversity and local livelihoods. The available literature relates mainly to the national monitoring, reporting, and verification processes. At field REDD+ pilot project scale, the range of approaches being tested is smaller but expanding, and is beginning to include more participatory and community-based approaches to monitoring because these may have greater resonance at the local level (Skutsch 2011, Mukama et al. 2012).

Despite the many scientific papers now being published on REDD+, the different ways it might be implemented, and the various consequences, good or bad, on forests, people, and biodiversity (Robledo et al. 2008, Chhatre and Agrawal 2009, Putz and Redford 2009, Venter et al. 2009, Ghazoul et al. 2010, Rights and Resources 2010, Fisher et al. 2011, Gardner et al. 2012, Strassburg et al. 2012), many of the papers remain primarily theoretical. This is partly because REDD+ projects are mainly readiness and pilot activities that have been started only in the past few years, and there has not been enough time to collect quantitative data and analyze relevant

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implementation lessons. Other papers have used REDD+ to reopen older debates on forest conservation and management through the new optic of carbon forestry.

Little has been published on existing efforts to involve local stakeholders in REDD+ implementation or on how community-based REDD+ should be undertaken in practice, including issues of community-level monitoring of carbon, livelihoods, or biodiversity. Past work does, however, suggest that community involvement in monitoring enhances feelings of ownership and improves governance while building local capacity (Andrianandrasana et al. 2005, Danielsen et al. 2005, Gibson et al. 2005). Moreover, local people's participation in monitoring has been shown to enhance decision-making at the operational level of forest management (Danielsen et al. 2007, 2010). Monitoring forest carbon, biodiversity, and livelihoods by local communities may, therefore, be one part of the foundations of a fair and equitable REDD+.

Previous studies have shown that communities can monitor biomass in relatively simple-structured forests, for example Tanzanian miombo (*Brachystegia*) woodland and temperate montane Himalayan oak (*Quercus*) and pine (*Pinus*) forests (Skutsch et al. 2011). However, not a single study yet reports data on the ability of local communities to monitor aboveground biomass (AGB) in the complex old-growth tropical forests of South America, Africa, or Southeast Asia, where the large number of species and difficulties of access make surveys much more challenging (Dam and Trines 2011).

Previous local monitoring protocols have also relied mainly on the use of handheld computers (Peters-Guarin and McCall 2011), which may represent a constraint to community involvement and the broad-scale implementation of the approach because capacity is limited in some communities (Howell 2012). Employing low-tech field approaches, such as recording of data using pen and paper, measuring using ropes marked at relevant points, and utilizing other feasible protocols for local communities, may greatly enhance the application of the approach.

Current conservation practice provides examples of how community monitoring of REDD+ might be able to develop. For example, the community forest conservation approach started in Nepal through policy changes in the 1960s and pilot projects in the 1970s (Acharya 2002, Kanel 2004), which have expanded to a national program covering more than 1.65 million ha of woodland and 2.18 million households (Anon. 2012*a*, *b*), and has been widely replicated around the world (Carter and Gronow 2005). Community monitoring of Tanzanian miombo and Himalayan oak forest both started as components of a donor funded research and capacity-building program (Skutsch 2011), and could therefore be regarded as isolated examples that could be driven by the researchers' funding rather than genuine community involvement. Alternatively, these approaches and their results may represent the beginnings of a broader movement, like community forestry in Nepal, that could self-replicate around the world and become a major element in reducing forest degradation and deforestation.

The other main considerations in the implementation of REDD+ in the field are political and can be framed in terms of power relations. The negotiations between the local, national, and international stakeholders in REDD+ mechanisms require a "level playing field" in terms of understanding and appreciating the quantitative aspects of emissions and emissions reduction. Clark et al. (2011) introduced the Salience, Credibility and Legitimacy Framework into the discussions of natural resource management. Knowledge products require all three attributes before they will be noticed and accepted as the basis for negotiations. Salience refers to the opportunity to relate results to policies and actions, credibility to the use of correct method and procedure, and legitimacy to the appropriate involvement of stakeholders. The discussion of community involvement in REDD+ may benefit from analysis along these lines.

We broadly address three issues related to the involvement of indigenous people and local communities in the implementation of REDD+ on the ground. First, we assess the ability of local communities to accurately estimate AGB in several forests across Southeast Asia using a simple-to-use methodology within national REDD+ programs. Second, we review current efforts to involve local communities in monitoring carbon, biodiversity, and livelihoods within forest carbon projects that are accredited by the Climate, Community and Biodiversity Alliance (CCBA) around the world. Third, we assess and discuss the application of community monitoring in REDD+ schemes and its implementation in the field, with emphasis on community forest management.

The specific questions we address are as follows:

1. How well can communities measure AGB in Southeast Asian forests?
2. To what extent has community monitoring been taken up in existing REDD+ programs?
3. How does the current situation on the ground link with the "intention" of the current UNFCCC texts on carbon monitoring and safeguards for the proposed REDD+ mechanism?
4. How will community monitoring of REDD+ projects become operational "at scale", beyond limited application in current pilots and research projects?
5. Does the involvement of communities in monitoring of forest carbon and REDD+ safeguards improve the chance of equitable and just implementation of this primarily climate change mitigation tool?

METHODS

Measurement of forest carbon

Study sites and data collectors

We collected new data from permanent vegetation plots in nine forest types of Indonesia, China, Laos, and Vietnam. Study sites were opportunistically chosen in the four countries. Among the selection criteria were the usage by local communities of the candidate forest sites and the potential for reduction of forest degradation.

In Central Kalimantan, Indonesia, plots were established in Batu Majang village, Kutai Barat District, in the Province of East Kalimantan, in lowland dipterocarp forest (40–500 meters above sea level [m.a.s.l.]; 400 ha). On forest margins, a few large trees were harvested by the local community, but most of this forest has remained unmanaged over the last decades (Rutishauser et al., *in press*).

The study area in China was in Man Lin village in Xiangming township of Xishuangbanna Autonomous Prefecture, Yunnan Province. It comprises tropical mountain forest at 900–1200 m.a.s.l. In total, 761 ha in two forest types were surveyed: slightly disturbed forest (470 ha) and moderately disturbed forest (291 ha), including overgrown swidden fields and areas with ancient tea trees mixed with natural forest vegetation.

In Laos, the study area was in Ban Sakok village, Viengthong District, Hauphan Province, and was in hilly evergreen monsoon forest between 600 and 1600 m.a.s.l. In total, 162 ha in two forest types (100 ha and 62 ha) were surveyed: primary closed forest and disturbed open forest surrounded by old and new swidden fields.

In Vietnam, the study areas were in Diem and Moi villages in Con Cuong District, Nghe An Province, within lowland evergreen monsoon forest between 160 and 460 m.a.s.l. In total, 314 ha in four forest types (125 ha, 104 ha, 67 ha, and 18 ha) were surveyed. The degree of disturbance varied from almost undisturbed forest to secondary forest, severely degraded forest, and forest regrowth in former swidden fields (Appendix 1).

Plots were measured by both community members and professional foresters between September 2011 and May 2012. Representatives of the local communities helped select community participants for the monitoring based on their interest and experience with forest resources; hence, these community members were probably more skilled than the average villager. All community monitors had attended primary school, and all received 1–2 days training in methods and approaches from intermediate organizations (research organizations and nongovernmental organizations [NGOs]). In addition, the intermediate organizations supervised the community monitors in mapping forest areas and locating plots with GPS devices for 3–5 days in each study area. The professional monitors all had academic degrees within natural science, and they had on average four years of work experience with forest assessments in practice.

All communities were in rural areas. The community in Kalimantan was connected to other communities only by river and relied mainly on subsistence agriculture, while the villages in China, Laos, and Vietnam were connected by road. Villagers in Laos and Vietnam sold part of their agricultural produce at markets, whereas villagers in China were involved in growing rubber in plantations and were relatively wealthier.

The different forest types monitored encompassed a wide range of land tenure and usufruct rights, i.e., communal forest (Indonesia), collective forest (China), State forest (China), and State forest with user rights allocated to villagers (Laos and Vietnam).

Methods for measurements of forest carbon

To measure forest biomass, we used a simplified version of the radial nested sampling methods described by Verplanke and Zahabu (2009) and Hairah et al. (2011a) (Appendix 2). Community members first identified total forest area on printed maps with the assistance of an intermediate organization (IO). Based on available knowledge of forest history (i.e., previous logging or swidden agriculture), the community members and the staff of the IO stratified the forest into homogenous strata (referred to as "forest type"), and these were treated as independent entities in the monitoring.

In each stratum, the community members and the staff of the IO established 15 randomly selected pilot plots so that the staff of the IO could determine the biomass stock variability and estimate the number of plots required to assess the biomass stock of the stratum with a coefficient of variation (C.V.) < 20% (Wagner et al. 2010).

Based on this pre-analysis, staff of the IO randomly chose the number and location of plots that were needed across the stratum and indicated these on a map. After this, community members on their own but supervised by one IO staff, and professional foresters independently carried out forest inventories in each plot with a maximum of four months in between.

All trees with girth ≥ 30 cm (as a proxy for diameter at breast height [DBH] ≥ 10 cm) and with girth ≥ 100 cm (DBH ≥ 30 cm) had their girth measured at 130 cm from tree base within a radius of 9 m and 15 m from plot center, respectively. In Vietnam and Laos, each measured tree was furthermore numbered to allow a tree-to-tree comparison of girth measurement between observers. IOs entered the data into Excel and estimated the total tree AGB using Brown's generic equation (Brown 1997). This practice is in line with the methodology recommended by the IPCC Good Practice Guidance (Penman et al. 2003).

Costs of community-based and professionally executed measurements were estimated on the basis of the actual expenses incurred for local transport and during the training and fieldwork.

We analyzed whether community members and professional foresters measured the same number of trees per plot, measured the same girth per tree, and recorded the same biomass per hectare estimated per plot. For the analysis of tree girth and number of trees per plot, we used Wilcoxon signed rank tests and a significance level of 0.05. The comparison of tree girths was possible only in Laos and Vietnam because the trees were marked individually in those countries. For comparing the biomass per hectare, we first square root transformed the data so they would fit a Gaussian distribution. We thereafter tested community data and forester data individually for outliers by identifying values that exceeded 3x standard deviations. If the outlying value of one data set did not parallel an outlying value of the other at the same plot, we excluded the corresponding plot because it was clearly identifiable as a miscalculated value. We then compared the mean biomass by a match-paired Student's t test and compared the variance by an F test.

Furthermore, to test whether the numbering of individual trees had an effect on the number of trees measured between community-based and professionally executed methods, we compared Vietnam and Laos to the rest of the countries regarding the proportion of plots with exactly the same number of measured trees using a χ^2 test (with software from Preacher 2001).

Finally, to explore the relationship between the number of community member and forester plots needed in a forest stratum and the biomass C.V., we applied a bootstrap procedure along which n plots were randomly selected 1000 times. From this distribution, we computed the biomass C.V. for both the community members and the professional foresters.

Assessment of uptake of community monitoring within existing REDD+ programs

To assess the extent to which community monitoring has been taken up in existing forest carbon programs, we located the project design documents for all projects that have been validated by the CCBA Standard (http://www.climate-standards.org/ccb-standards/), which is one of the most widely used forest certification standards (Merger et al. 2011).

The CCBA Standards apply to land-based carbon projects that (1) "reduce greenhouse gas emissions through avoided deforestation and forest degradation (REDD)" and (2) "remove carbon dioxide by sequestering carbon (e.g., reforestation, afforestation, re-vegetation, forest restoration, agroforestry and sustainable agriculture)" (CCBA 2008, p. 7).

We used five categories to determine the degree of local stakeholder involvement in the monitoring, broadly following the monitoring typology established by Danielsen et al. (2009). These categories are easy to extract objectively from the CCBA project design documents and are clearly separate from each other:

1. There is no involvement of local stakeholders in monitoring.
2. Local stakeholders assist in, or conduct parts of monitoring, but professional foresters are actively involved in on-the-ground monitoring activities.
3. Local stakeholders conduct all on-the-ground monitoring themselves, but reporting and analysis are done by professional foresters.
4. Local stakeholders conduct all on-the-ground monitoring and report the data to a central unit independently and/or actively participate in the design and implementation phase of the monitoring scheme. Professional foresters conduct the analysis of the monitoring data.
5. Local stakeholders participate in the design and implementation phase of the monitoring scheme, conduct all on-the-ground monitoring, and report and analyze all on-the-ground data themselves.

For all CCBA monitoring schemes, an independent verification of the monitoring process and data from a third party are required; thus, we see verification as an autonomous program that does not influence the degree of participation by local stakeholders in monitoring. For the purpose of an analysis of uptake of community monitoring within existing REDD+ programs, we defined local stakeholders as local resource users or local government staff.

We used Pearson's χ^2 test (with software from Preacher 2001) to compare the degree of local stakeholder involvement between CCBA-validated project types (REDD+ vs. no REDD+; Forest Enhancement vs. Reduced Forest Degradation), and between the continents. To investigate if projects involving local stakeholders in one type of monitoring were also more likely to involve them in others, we conducted a Simpson's similarity measure between carbon, biodiversity, and livelihood monitoring (Koleff et al. 2003). We compared the observed Simpson's similarity against 1000 randomizations of monitoring schemes (or bootstrapping) and tested whether they were higher than expected if there was no linkage between types.

Linking reality on the ground to United Nations Framework Convention on Climate Change texts

We reviewed the text of the current proposed REDD+ mechanism (decision 1/CP.16) and the proposed text for the biodiversity and livelihoods safeguards (decision 1/CP.16, its

Table 1. Measurements of aboveground biomass (AGB) by local community members and professional foresters in four Southeast Asian countries, with p values for total biomass estimates (matched pair ttest) and variance (F test), tree girth measurement (Wilcoxon signed rank test), and plot demarcation (Wilcoxon signed rank test) (n = 289 permanent plots). Significant values are shown in bold (n.a. = not available).

Country	Name of area (site number)	Number of plots	Community survey of biomass (Mean AGB in Mg · ha-1)	Forester survey of biomass (Mean AGB in Mg · ha-1)	Biomass estimates (square root transformed) p	Variance of biomass estimates (square root transformed) p	Tree girth (cm) p†	Plot demarcation (Tree inclusion and exclusion) p†
Indonesia	Batu Majang (a)	64	381‡	449‡	**<0.01‡**	**0.048‡**	n.a.§	**< 0.01 (20%)**
China	Manlin (b)	30	332	303	**<0.01**	0.51	n.a.§	0.26 (23%)
China	Manlin (c)	30	235	219	0.32	0.34	n.a.§	0.15 (0%)
Laos	Sakok (d)	32	293	301	0.21	0.57	**< 0.01 (38%)**	n.a. | (97%)
Laos	Sakok (e)	30	204	208	**0.02**	0.41	**< 0.01 (53%)**	n.a. | (88%)
Vietnam	Diem (f)	30	106	104	0.34	0.34	0.60 (47%)	**0.02 (60%)**
Vietnam	Moi (g)	18	105	105	0.56	0.63	0.051 (54%)	0.67 (22%)
Vietnam	Moi (h)	28	89.0	88.9	0.94	0.46	0.38 (53%)	0.05 (50%)
Vietnam	Moi (i)	27	50.7‡	52.3‡	0.20‡	0.41‡	**0.02 (47%)**	0.38 (56%)

†In brackets, the proportion of measured trees (tree girth) and plots (plot demarcation) where community members' and foresters' measurements had a perfect match.
‡One plot was excluded because it violated 3x standard deviation of the mean. (For Batu Majang, Indonesia, n = 63; for Moi [i], Vietnam, n = 26)
§ Data are not available because trees were not individually marked.
| No p value is available because too few degrees of freedom exist for Wilcoxon's signed rank test.

Appendix 1) to determine the degree to which community monitoring and the involvement of local people was mentioned in the official documents in comparison to the field realities in countries with CCBA-accredited projects. We also searched the various UN-REDD guidance documents for information on how safeguards are addressed and respected (UNFCCC/SBSTA/2011/L.25/Add.1) and the draft decision of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA Draft decision [-/CP.17] 2011).

RESULTS

How well can communities measure carbon in Southeast Asian forests?

Biomass

With a square root transformation of biomass estimates, all sites showed a clear normal distribution (Shapiro-Wilk $p > 0.05$, compared with visual identification). Two plots were excluded due to violations of 3x standard deviation (s.d.): one in Batu Majang, Indonesia (3.87x s.d.) and one in site (i) in Moi, Vietnam (4.23x s.d.). Both were due to outlying values among community measurements.

Overall, the aboveground biomass estimated by community members differed only slightly from the estimates of professional foresters (Fig. 1, Fig. 2, Table 1). However, the difference was significant in one-third of the sites (three sites out of nine) (ttest, $p < 0.05$; Table 1).

To explore the precision of measurements by community members and professional foresters, we compared the variance of biomass estimates and found that there was significant difference at only one site out of nine (F test, $p < 0.05$; Table 1). Moreover, we examined the relationship between the number of plots needed in a forest stratum and the biomass C. V. (Fig. 3). In Batu Majang, Indonesia, to obtain the same precision as foresters, the community members would need to sample twice the number of plots—i.e., to achieve a C.V. of 15%, community members would need about 30 plots, while foresters would require only 15 plots (Fig. 3a). Likewise, in Moi (Vietnam), to obtain a C.V. of 15%, the community members would need about 20 plots but foresters would need only 15 plots (Fig. 3g). In contrast, in Manlin (China), Sakok (Laos), and Diem (Vietnam), the local community members had approximately the same precision as the foresters (Fig. 3b, c, d, e, and f).

Tree girth

In Laos and Vietnam, trees were numbered by the community members and remeasured by professional foresters. At these sites, we investigated the difference in girth measurement among both types of observers. At three out of six sites, two in Laos and one in Vietnam, there were significant differences between community monitors and foresters, but a high proportion of the trees was measured exactly the same at the measuring tape's resolution of one centimeter (Table 1).

Fig. 1. Relationship between the aboveground woody biomass recorded by community members and forester plot-based aboveground biomass measurement in lowland dipterocarp forest in Batu Majang, Indonesia (a), mountain rain forest in Manlin, China (b–c), evergreen monsoon forest in Sakok, Laos (d–e), and Diem (f) and Moi (g–i), Vietnam (with same units on y-axes as on x-axes and y = x lines; n = 289 permanent plots). Each point in the graphs represents one census of aboveground woody biomass in a permanent plot by community members (y-axes) and foresters (x-axes).

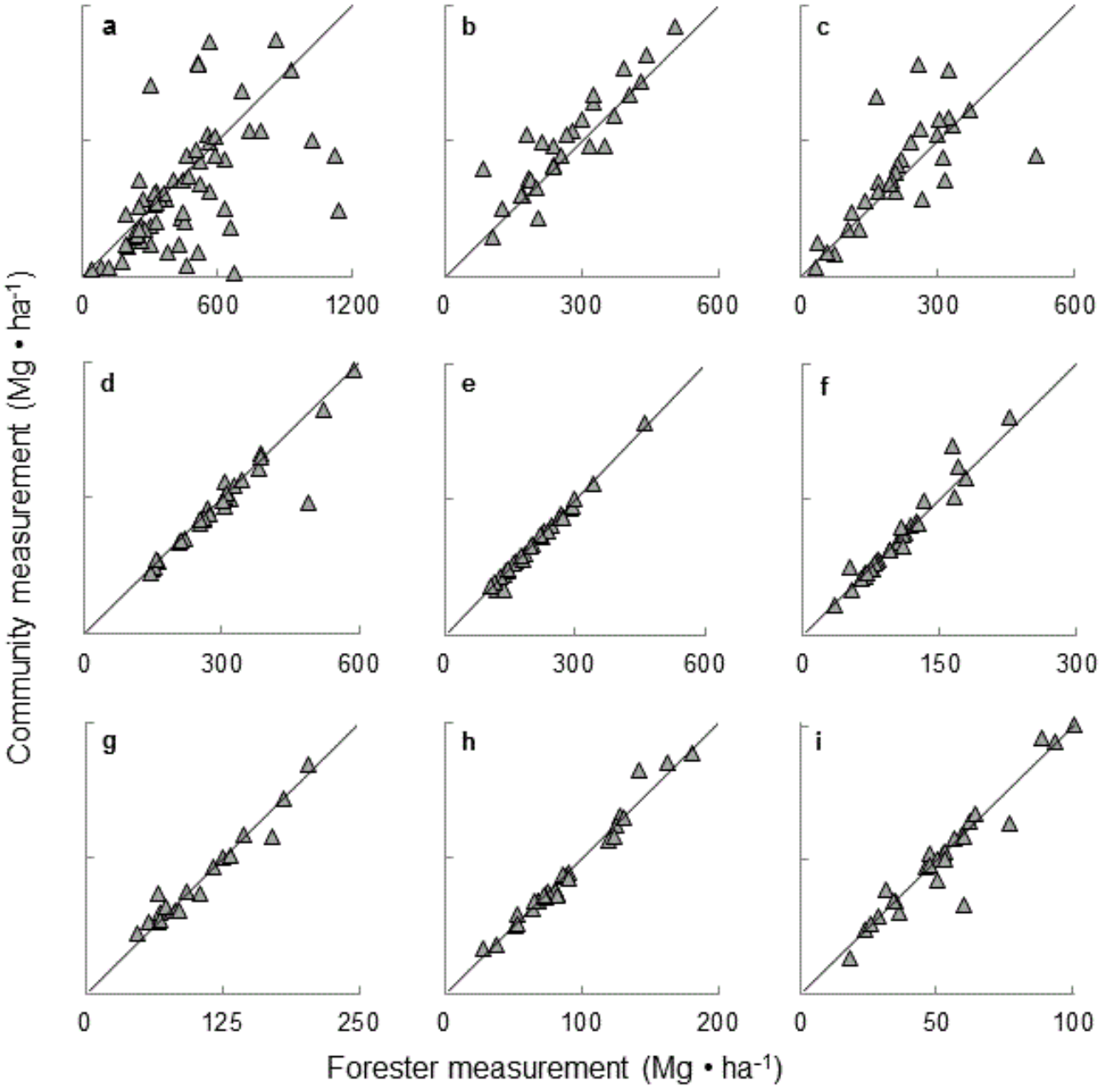
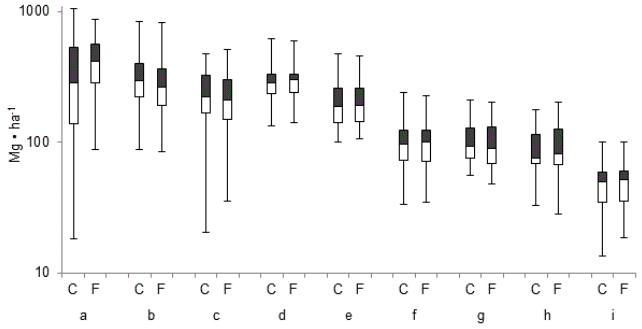


Fig. 2. Comparison of woody biomass data in diverse Southeast Asian forests compiled by community members and professional foresters. Measurements of aboveground woody biomass were made by community members (C) and foresters (F) over a range of lowland dipterocarp forest in Batu Majang, Indonesia (a), mountain rainforest in Manlin, China (b–c), evergreen monsoon forest in Sakok, Laos (d–e), and Diem (f) and Moi (g–i), Vietnam ($n = 289$ permanent plots; log10 scale). The different points in each column show the smallest observation, lower quartile, median, upper quartile, and largest observation.



Further analysis revealed that the distribution of differences in girth measurements was slightly skewed (Appendix 5). Villagers consistently measured slightly lower girths than foresters. However, we found high kurtosis values of the distribution modes, indicating high agreement between the community members and the professional foresters for most girth measurements (Appendix 5).

Plot demarcation

The analysis of the plot demarcation efforts of the community monitors (the inclusion or omission of trees in plots) showed that in both countries where trees were numbered individually, i.e., Vietnam and Laos, there was a much higher percentage of plots where community monitors and foresters found exactly the same number of trees (χ^2 test, $p < 0.01$).

Costs

We estimated the costs of monitoring forest biomass by community members and by foresters on a per plot basis. We found that, from an external perspective, the community measurements of aboveground biomass in the first year cost US$39–$82 per plot, whereas forester-executed biomass measurements cost US$22–$53 per plot (Table 2, Appendix 3). Community measurements required more funds for training but there were higher expenditures for travel, accommodation, and salaries for professional forester measurements (Table 2).

To what extent has community monitoring been taken up by existing REDD+ pilot projects?

To date (April 13, 2012), 50 forest carbon projects have been validated by the CCBA. From the project design documents, we were able to retrieve information on 50 biomass/carbon, 47 biodiversity, and 48 livelihood monitoring schemes (data set in Appendix 7).

Our analysis showed that 48% (24) of the CCBA-validated projects had no planned involvement of local stakeholders in monitoring, as illustrated in Fig. 4. At the other end of the spectrum, 12% (6) of the CCBA-validated projects involved local stakeholders in monitoring biomass, biodiversity, and livelihoods (Appendix 7).

We found that CCBA projects involving local stakeholders in monitoring biomass often also involved local stakeholders in monitoring biodiversity ($S_{Sim} = 0.92$), whereas we found no correspondence between schemes that involved local stakeholders in monitoring livelihoods and schemes that involved locals in monitoring biomass or biodiversity (livelihood and carbon $S_{Sim} = 0.5$; livelihood and biodiversity $S_{Sim} = 0.57$).

The involvement of local stakeholders in CCBA monitoring varied across the continents (Appendix 6). Community carbon monitoring showed a pattern towards being widespread in Africa ($p = 0.12$, $n = 13$) and less common in North America ($p = 0.12$, $n = 9$). Likewise, community biodiversity monitoring was significantly more common in Africa ($p = 0.03$) and less common in North America ($p = 0.03$).

The involvement of local stakeholders in CCBA monitoring also varied across time. Between July 2009 and April 2012, CCBA projects increasingly involved local stakeholders in monitoring of biodiversity, biomass, and livelihoods (Fig. 5). Finally, local involvement in CCBA project monitoring was more frequent in "reduced forest degradation" schemes than in "forest enhancement" schemes (Table 3).

Is field practice in line with the "intention" of the REDD+ and safeguards texts?

The UNFCCC calls for the development of a "system for providing information on how safeguards are being addressed and respected through the implementation of [REDD+] activities" (UNFCCC Decision 1/CP.16 p71d). Likewise, the UNFCCC specifically calls for "ensuring the full and effective participation of relevant stakeholders, *inter alia*, indigenous peoples and local communities" (UNFCCC Decision 1/CP.16 p72). The last quote refers to participation in general and not directly to monitoring activities. Appendix 1 of the REDD+ text specifies that activities should promote and support "Respect for the knowledge and rights of indigenous peoples and members of local communities, by taking into account relevant international obligations, national circumstances and laws," and reiterates "the full and effective participation of

Table 2. Cost of community and professional forester-executed measurements of biomass in the study areas in Indonesia, China, Laos, and Vietnam (details in Appendix 3). All costs are in US$.

Country	Name of area (site number)	No. of plots	Data gatherer	Training and supervision†	Travel and accommodation for data gatherer	Food for data gatherer	Equipment	Wages	Total cost year 1	Estimated total cost year 1–4	Total cost per plot year 1	Estimated total cost per plot per year 1–4
Indonesia	Batu Majang (a)	64	Community	2212	0	146	48	435	2841	6392	44	25
Indonesia	Batu Majang (a)	64	Professional	0	385	353	15	1887	2640	7332	41	29
China	Manlin (b–c)	60	Community	2218	0	0	20	384	2622	5634	44	23
China	Manlin (b–c)	60	Professional	0	416	48	0	836	1300	5200	22	22
Laos	Sakok (d–e)	62	Community	2944	0	0	211	526	3681	11177	59	45
Laos	Sakok (d–e)	62	Professional	0	2263	0	288	750	3301	11376	53	46
Vietnam	Diem (f)	30	Community	2198	0	58	95	100	2451	5153	82	43
Vietnam	Diem (f)	30	Professional	0	475	554	11	255	1295	5180	43	43
Vietnam	Moi (g–i)	73	Community	2098	0	255	181	343	2877	8897	39	30
Vietnam	Moi (g–i)	73	Professional	0	950	1152	11	510	2623	10492	36	36

†Including travel, accommodation, food and wages for trainers

Table 3. Proportion of Reduced Forest Degradation and Forest Enhancement forest carbon projects validated by the Climate, Community and Biodiversity Alliance (up to April 13, 2012) that involve local stakeholders in monitoring carbon, biodiversity, and livelihoods.

	Carbon	Biodiversity	Livelihood
Reduced Forest Degradation projects (n = 17)	47% (n = 17)	53% (n = 17)	25% (n = 17)
Forest Enhancement projects (n = 33)	15% (n = 33)	27% (n = 30)	31% (n = 32)
Pearson's χ^2 †	p = 0.04	p = 0.07	p = 0.91

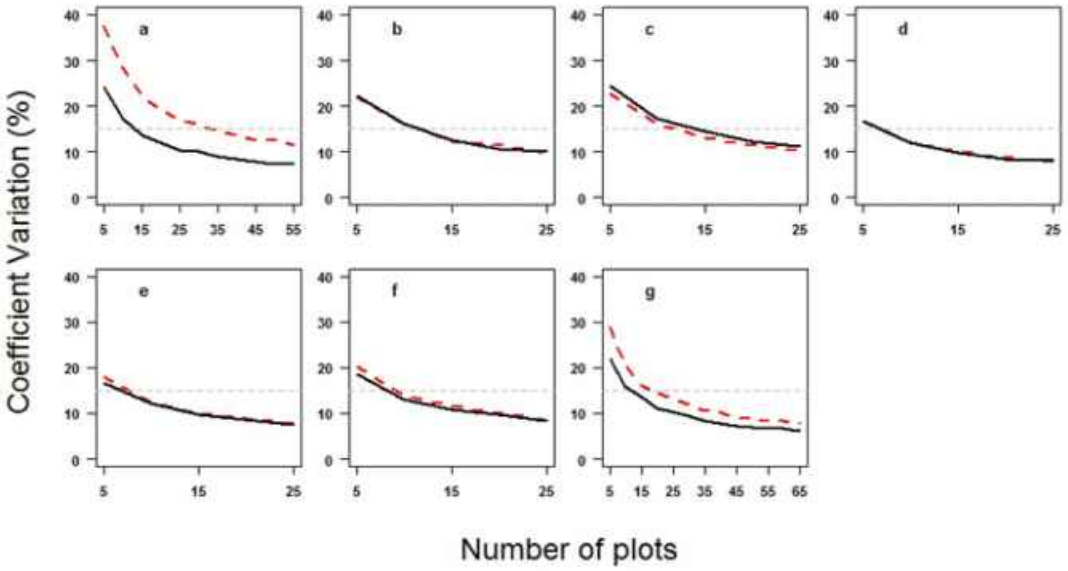
†Between Reduced Forest Degradation projects and Forest Enhancement projects

relevant stakeholders, in particular, indigenous peoples and local communities" (UNFCCC Decision 1/CP. Appendix 1 c–d).

To be able to participate in, and implement any future activities aimed at reducing emissions from deforestation and forest degradation, developing countries will need national monitoring systems to improve their data collection systems and their estimation and reporting of emissions. The Subsidiary Body for Scientific and Technological Advice (SBSTA) recommended draft decisions on how safeguards are addressed and respected, and modalities related to forest reference emission levels and forest reference levels for adoption by the Convention of Parties at its seventeenth session in Durban (UNFCCC/SBSTA/2011/L.25/Add.1). The document provides principles for national reporting systems. However, there is no detail on how indigenous peoples or local communities can participate in such information systems. Likewise, in its draft decision, the Ad Hoc Working Group on Long-term Cooperative Action under the Convention merely recommends "promot[ing] and support[ing] the safeguards referred to in decision 1/CP.16, Appendix 1, paragraphs 2(c)–e)" (AWG-LCA [-/CP.17] 2011).

Despite the intention of full and effective involvement of indigenous peoples and local communities, guidance on how to implement this in practice is wanting. Rather, the UNFCCC REDD+ text notes that "safeguards should support national strategies" and "take into account national circumstances and respective capabilities, and recognizing national sovereignty and legislation, and relevant international obligations and agreements." As it stands, the degree of participation is likely

Fig. 3. Relationship between the number of plots and the coefficient of variation for forest biomass measurements by community members (stippled red line) and professional foresters (black line) in lowland dipterocarp forest in Batu Majang, Indonesia (a), mountain rain forest in Manlin, China (b–c), evergreen monsoon forest in Sakok, Laos (d–e), and Diem (f) and Moi (g), Vietnam (with coefficient of variation = 15% dashed line; n = 289 permanent plots). Data from the three sites in Moi were lumped together for the purpose of preparing this figure.



to follow existing national methodologies and policies, and hence may be biased in favor of technocratic solutions to REDD+ needs, and may promote the exclusion of local people. In some instances, however, existing national legal frameworks may favor local involvement, for example in countries with progressive community forestry laws and implementation. In others, the REDD+ text may serve to maintain a low level of community participation. Currently, the limited involvement of local stakeholders in REDD+ monitoring in practice seems to be in contrast to the intended full and effective participation as stated in the UNFCCC REDD+ text.

DISCUSSION

Scope, strengths, and weaknesses of community monitoring for REDD+

Following Clark et al. (2011), from a power relations perspective, knowledge products such as REDD+ monitoring results require three attributes before they will be accepted as the basis for negotiations: salience, credibility, and legitimacy. Salience refers to the opportunity to relate results to policies and actions, credibility to the use of correct method and procedure, and legitimacy to the appropriate involvement of stakeholders.

On the salience and legitimacy side, the arguments in favor of involving local communities in monitoring local REDD+ are unequivocal. As greenhouse gas emissions are currently generally the result of the interaction of external and local agents (Meyfroidt and Lambin 2011), local agents will have to be involved in any effort to change from business as usual, and the more this can be discussed on an equal footing and on a level playing field (Agrawal et al. 2011), the higher the chance will be that issues are diagnosed in sufficient depth, solutions are comprehensive, and resistance to change "to meet foreign agendas" is minimized.

On the credibility side, however, there are both challenges and opportunities in combining local knowledge of the environment and the reporting formats needed at the national and international level. In local knowledge systems, quantitative estimates are relevant for estimating how much wood a tree can yield after logging or which species produce good timber or firewood or charcoal, but otherwise, a more qualitative language is often sufficient. Carbon stocks, on the other hand, are abstract concepts and are only relevant insofar as external agents start using these terms and discuss performance-based contracts expressed in such units.

Whereas local REDD+ implementers should not be involved in technical aspects of mathematical calculations of carbon

Fig. 4. Involvement of local stakeholders in monitoring forest biomass (black), biodiversity (shaded), and livelihoods (white) in forest carbon projects validated by the Climate, Community and Biodiversity Alliance (CCBA) (up to April 13, 2012) (n = 50 forest carbon schemes). The degree of involvement of local stakeholders increases from left to right along the x-axis: 1. no involvement of local stakeholders in monitoring; 2. local stakeholders assist in, or conduct parts of, monitoring but professional foresters are actively involved in on-the-ground monitoring activities; 3. local stakeholders conduct all on-the-ground monitoring themselves but reporting and analysis are done by professional foresters; 4. local stakeholders conduct all on-the-ground monitoring and report the data to a central unit independently, and/or actively participate in the design and implementation phase of the monitoring scheme, and professional foresters conduct the analysis of the monitoring data; 5. local stakeholders participate in the design and implementation phase of the monitoring scheme, conduct all on-the-ground monitoring, and report and analyze all on-the-ground data themselves.

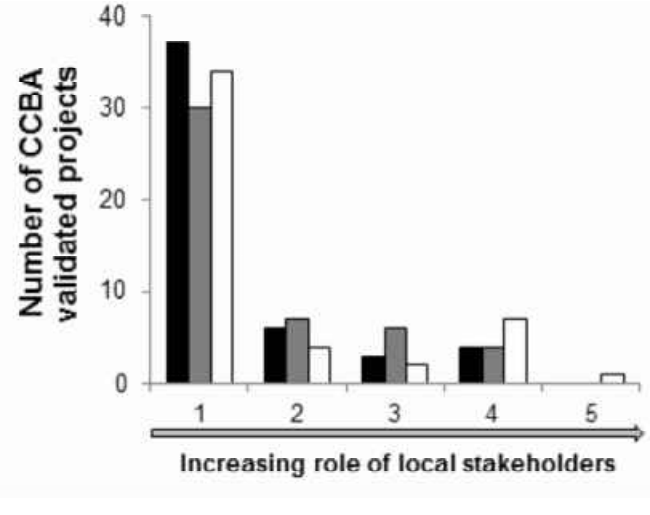
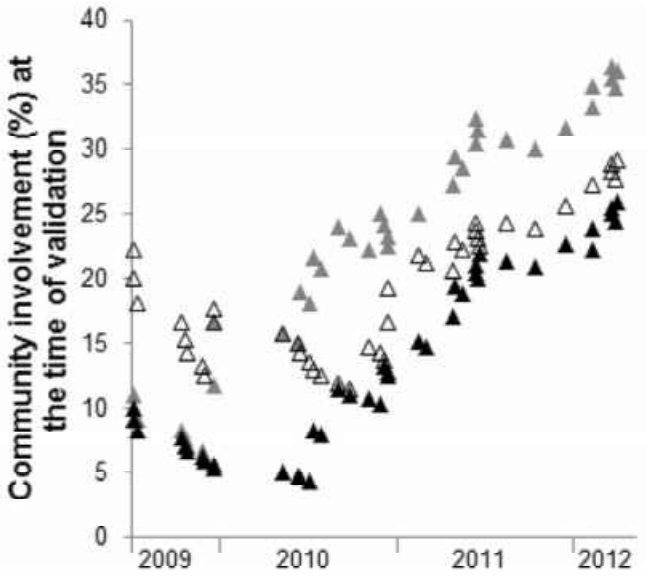


Fig. 5. The trend over time in the involvement of local stakeholders in monitoring forest biomass (black triangle), biodiversity (shaded triangle), and livelihoods (white triangle) in forest carbon projects validated by the Climate, Community and Biodiversity Alliance from July 2009 to April 13, 2012 (n = 50 forest carbon schemes). The monitoring schemes with local stakeholder involvement belong to categories 2 to 5 in Fig. 4.



stocks, their involvement in the measurements of forest carbon stocks is likely to secure compensatory payment for standing trees. The clerical skills needed to record tree girth data do not require much beyond primary school reading and writing, but the next steps in processing do. Therefore, biomass monitoring manuals that use look-up tables rather than allometric power functions are very helpful. Hairiah et al. (2011b), in the Indonesian language, cater to this, while the English version (Hairiah et al. 2011a) does not.

Beyond recording the trees in an agreed plot, the process for randomly identifying a plot within an agreed stratum, and a locally fine-tuned approach to stratified sampling are very novel concepts at the local level, without obvious local rationale or utility outside of a REDD+ context in the study areas. However, in other countries, like Mexico, where communities are involved in timber harvesting, such forest inventories for volume assessments are commonly carried out (Skutsch 2011). Moreover, there is relatively little space for local adjustments to the community forest biomass monitoring methods. In the worst case, local monitoring degrades to the use of lowly paid or unpaid labor for what is essentially an external agenda. If the REDD+ process leads to other types of important local benefits, this may, however, be justified.

The key opportunity from community monitoring is that it can provide a locally credible estimate of carbon stocks that can directly benefit the local stakeholders.

Quality of data collected through community monitoring

In our comparison of community members' and professional foresters' measurements of forest biomass, we found that community members obtained similar forest biomass estimates as professional foresters but with statistically significant bias in three out of nine forest strata that were assessed. However, further analysis revealed that there are easily understandable reasons for this bias.

When comparing the girth measurements alone, two sites in Laos and one in Vietnam had significant difference between community and forester measurements of girth (Table 1). At these sites, we found small discrepancies across all size classes of trees (Appendix 4 d, e, and i). Likewise, when comparing the tree demarcation alone, there were significant differences between community and forester demarcation of plots at only two sites, one in Indonesia and one in Vietnam (Table 1). One possible explanation for the discrepancies at these sites could be due to a lack of measurement experience; another could be accidental double counting by the professional forester. Another possible explanation is that positioning a plot with a GPS that has a precision of 5–20 m is difficult. Hence, without marking the trees and the plots, it is difficult to account for the same trees. In complex tropical forests, large trees with buttresses (and the way they have been measured [above/on buttresses]) are likely to cause significant differences in biomass stock assessment. Whatever the reason, with repeated measurements and further training, the capacity of all monitors, community members and foresters alike, should improve, which would reduce the number of errors.

The largest errors recognizable in the data were three notational errors on circumferences (one in Vietnam and two in Indonesia) where trees were assessed as 2–5 m larger by community monitors than by the foresters. The two plots affected were removed from the analysis of the accuracy of biomass estimates because they were clear erroneous outliers, both from their respective remeasurement results and from the remaining plots in their respective sites. These errors were easily identifiable and occurred in only two out of 289 plots, but they highlight the necessity of proper validation of community measured field data. In other cases, for example in China, difference in community members' and professional foresters' measurements of biomass (Table 1) could be caused by only small but systematic discrepancies in the girth measurements across several size classes of trees (Appendix 4 b). Overall, the numbers of trees found within each size group by community members and foresters were similar, apart from small (32–64 cm circumference) trees in one site (Appendix 4 c).

At this and other sites, our observations suggest that particular attention must be paid to training community members in measuring trees with very large or difficult-to-measure stems because inaccuracies in their measurement have a large effect on the biomass estimates. For example, the girth of large trees was sometimes estimated instead of measured due to tall buttresses.

Status of community monitoring in REDD+ schemes

Our analysis of CCBA validated REDD+ schemes, to our knowledge the first of its kind, shows the gap between policy and practice. In the UNFCCC texts of REDD+ and in the increasing amount of guidance material available, there are strong statements on the need for indigenous people and local communities to be included in the process at national and subnational levels. But our review suggests that the present inclusion of local communities in one of the areas where they are well placed to engage locally based monitoring of forest carbon, biodiversity, and livelihoods is not particularly strong. However, it is improving as projects become more embedded on the ground and it is time to start bringing in those elements that are embodied in the REDD+ safeguards.

In order to further engage local communities in monitoring related to REDD+, and hence improve the social justice of this global mechanism, we suggest further development of methodologies for incorporating indigenous peoples and local communities into the monitoring of REDD+ (Phelps et al. 2010, Fry 2011). Activities can be based on established participatory principles and experience. Hereby, progress may be made towards respecting safeguards using simple techniques that are already available. While our experience is based on site-specific projects, the same basic principles and methods can be applied within subnational projects, possibly as part of the UNFCCC process. This would serve to help close the gap between intentions on participation and field practices within REDD+.

There are some potential biases in our analysis of the level of community involvement in the monitoring of REDD+ within the existing CCBA schemes. For example, some project design documents do not contain the full monitoring plan. It is also sometimes ambiguous which player conducts the monitoring. Therefore, our estimate of community involvement could be conservative. This applies especially to biodiversity and livelihood monitoring but also to some extent carbon monitoring. In addition, the style of the documents also changes through time. They become better at describing the specific role and training of local communities throughout the project, and better at responding to the political decisions at the level of the UNFCCC. Overall, we consider our estimates acceptable for the purposes of this paper, although figures from individual schemes are subject to uncertainty.

Links between national monitoring, reporting, and verification, and community monitoring

Ideally, community monitoring should be embedded within a process that feeds data to the levels at which subnational and national governments operate. In this section, we describe the links between national REDD+ monitoring, reporting, and verification (MRV) and community monitoring (adapted from Danielsen et al. 2012).

The national REDD+ program should ensure that involved communities are compensated for their labor to avoid taking advantage of local free labor. The involvement of communities in REDD+ MRV must be supported by national policy so that sufficient funds and staff can be set aside for the development

of the community monitoring component in the national REDD+ program.

In Laos and Vietnam there are already community-based organizations (CBOs), and in China and Indonesia there are individuals with experience in community forest monitoring initiatives. These CBOs, or other institutions representing communities, should be encouraged to take a central role in the design, development, and piloting of the community monitoring component of the national REDD+ program. It is advisable to start small, and see what works, and then expand as experiences accumulate (Herold and Skutsch 2011).

At the national level there is a need for a standard for community forest monitoring so that the same approach is used across all sites throughout the country. The standard should describe the requirements in terms of format of the raw data (measurements of tree girth, wood density) and auxiliary supporting information (location, date). Additional needs for data on forest resource status and forest governance developments should also be described. The standard should also describe how and when the data are transmitted from the CBO to the government.

The standard should represent a limited number of variables, measured more simply than in a general national inventory. These data should be presented in a form that could dovetail into the national system so that it could condense the national-level information by concentrating more sample plots in those areas that are being managed by communities. For example, the national inventory could have permanent plots at 5-km intervals across its entire forest territory, and these plots could then be conglomerates with several sample plots within each of them in which a whole host of variables are measured, once in five years. The community measurements could provide richer (more samples per hectare, and possibly annual measurements) data on carbon, and possibly biodiversity, in those areas where communities are operating. This could also help the decision-makers behind the national program assess whether the community forest management policies being promoted are successful.

Within the national REDD+ program, the specific roles of national staff, CBO staff, and community members should be agreed upon. There should be procedures described on how to collect, verify, check, process, and analyze the data (Pratihast and Herold 2011). Quality checking requires comparison of random spot checks with data sets from other sources. The national REDD+ program should inform the CBOs and communities with regard to signs of displacement of carbon emissions from unplanned forest loss and degradation in adjacent forest areas under REDD+ schemes. It requires process time and strengthened connection between the national REDD+ staff and the CBOs, but this information will be needed for the communities to claim REDD+ credits.

It is important to give government staff time to provide feedback to the communities, not only in terms of questions related to their data but also in terms of helping communities solve the broader land management issues that they experience. There will be a need for regular supervisory visits to the CBOs and communities on the part of the national and subnational REDD+ staff. This can often be appropriately undertaken by government staff with experience in Participatory Rural Appraisal techniques and in holding dialogues with community members.

Will community-based monitoring become a mainstream activity within REDD+ implementation?

The evidence from the international negotiations over REDD+ strongly suggest that in order for REDD+ to be accepted internationally, local people will have to receive some share of the benefits, whether as cash or development. Therefore, monitoring will be tied to payments or other benefits, and there may be a conflict of interest that has to be resolved.

At present, the majority of community-based forest monitoring schemes were started by research projects or conservation and development projects. Although some of these schemes seem reasonably self-sustaining (Stuart-Hill et al. 2005, Funder et al. in press), they are going to need to be greatly expanded in number, scale, and spread if they are to make any meaningful impact on the field monitoring of REDD+ at global (or even national) scales. We outline some of the ways that this might happen.

For REDD+ that is implemented using community forestry approaches, monitoring by local people could be part of the forest management agreement and tied to payments. However, because there may be incentives to falsify data if the results are linked to financial flows (e.g., Nielsen and Lund 2012), strong third party verification will be required. Experience from community wildlife monitoring, where financial flows are linked to management activities, details how successful benefit sharing has been emerging over the past few years. In the community wildlife management schemes of Namibia, for example, benefits to communities come from hunting and tourism, and the monitoring of wildlife populations, and management events, are wholly community based (event book system). Cross-checks are provided by the government, and there is strong NGO and donor support. This system has been running for more than a decade (Stuart-Hill et al. 2005).

Alternative approaches might also be considered. If we assume that national scale MRV is going to remain an area of technical expertise provided from the remote sensing and forest plot inventory communities, then community-level monitoring will be undertaken in project areas on the ground where there is a strong link between community management of the forest and carbon payments. Simply due to logistical reasons, large scale community-based REDD+ monitoring is unlikely to happen across the vast and remote forests of the Amazon or

Congo, or the miombo woodlands of Africa. There are simply too few people and too many trees for the approach of community REDD+ monitoring to work. But in areas where there are moderate numbers of people and moderate amounts of remaining forests and management regimes that are community friendly, then the approach has potential. It also seems unlikely that community monitoring will flourish within state managed protected areas. Community-based monitoring can also provide detailed on-the-ground measures to complement the more top-down approaches of remote sensing and inventory plots.

Following from the literature on other kinds of Payment for Ecosystem Service (PES) (Jack et al. 2008) schemes, the theoretical premise of conditionality and direct linkage to output of services in payments is often not upheld, and payments to communities are made on a per hectare basis for kinds of land uses in many cases of what has been described as PES (e.g., Lopa et al. 2012). This annual payment mechanism is simple to administrate and does seem to deliver considerable benefits in terms of changes in land use.

Finally, community monitoring and the detailed data that might be collected can be used to (a) cross-check estimates from remote sensing or models derived from limited numbers of inventory plots, (b) provide community engagement, (c) meet social requirements of REDD+ and ensure that the process is more equitable and just, and (d) convince foresters that there is some useful work that can be done at the community level.

Where REDD+ is implemented using tree planting approaches, there are already many examples of local people measuring trees that they have planted on their farmlands and receiving payment for the growth (and carbon capture) of these trees. Examples of these programs, with periodic third party verification, are provided by TIST (Kenya, Uganda, India: http://tist.org/tist/kenya.php), EcoTrust (Uganda: http://www.irinnews.org/report/95784/uganda-plant-trees-get-paid), and Scolel Té (Mexico: http://www.planvivo.org/projects/registeredprojects/scolel-te-mexico/).

In those forms of REDD+ that will be implemented through logging concessions committed to reduced impact logging practices, or through improved management of protected areas, involvement of local communities in the management of the concession or protected area, and hence in any monitoring, will depend on local agreements. The scope for involving local people in monitoring in protected areas and concession areas depends on the extent of community access and rights associated with these areas (as well as the government policies).

Finally, where REDD+ might be implemented through improving the efficiency of biomass burning in kilns for charcoal production or cooking stove efficiency for charcoal and firewood use, project effectiveness measurements might focus on amounts of wood used as firewood for cooking or for the production of a kilogram of charcoal but would still have to be linked to evidence of higher carbon stocks in the landscape. Community-based monitoring of efficiency of production and use of biomass fuel could be established but would be in different form to that outlined above.

To our knowledge, none of the above has been studied in any scientific research, and options for community involvement across the spectrum of potential REDD+ implementation approaches remains an open field for future work.

Could community monitoring promote equitable and "fair" REDD+ implementation?

Over the past 25 years, developing countries have transitioned toward decentralized forest management that allows local actors increased rights and responsibilities, and this has helped protect forests in many regions (Colfer and Capistrano 2005, Agrawal et al. 2008, Agrawal and Ostrom 2008).

Concerns have been raised that REDD+ is poised to reverse this trend (Phelps et al. 2010). In response to the new global discourses and understandings about unsustainable forest management and the role of forests in climate change mitigation, there is a growing set of international agreements with the potential to bring forests into a whole new fold of global institutions, capital flows, and policies (Sikor 2010). The emergence of new globalization tendencies suggests a need for a fresh look at key forest justice issues. Local participation in monitoring relates to a number of the six themes of forest justice: property, knowledge, governance, social norms of justice, value, and access, as defined by Sikor (2010).

Through participation in monitoring, indigenous peoples and communities may:

1. strengthen their position to gain rights to forests from which they were historically excluded (Larson et al. 2010)
2. feel recognized for their knowledge of forests. They may feel empowered to participate in REDD+ actions on more equal terms (van Laerhoven 2010)
3. be more motivated to contribute to forest protection as they have enhanced trust in the credibility of data and REDD+ actions (Chhatre and Agrawal 2008)
4. derive enhanced benefits from REDD+ either through compensation for the costs of monitoring or through better opportunities for development of benefit-sharing mechanisms (Edwards et al. 2010, Corbera and Schroeder 2011)
5. strengthen their position to obtain or maintain access to culturally and economically important forest areas (Brockington 2007, Schwartzman et al. 2010)

In short, there are strong reasons of justice as to why communities should be involved in monitoring for REDD+. This corroborates past forestry research that has emphasized the exclusionary nature of (scientific) knowledge on forests (Sikor 2010).

Bottlenecks for scaling up of community monitoring for REDD+

There are several bottlenecks for the large scale adoption of community approaches to monitoring REDD+. Our study addressed a few issues, but further studies are needed to address these issues more systematically and at larger scale.

In terms of training and capacity building, "technical foresters" are taught mainly professional forestry methods of remote sensing and inventory, while the curriculum for "social foresters" does not prepare them for technical aspects of monitoring carbon stocks (Gregersen et al. 1989). There is low awareness of simple low-tech methods, or the potential benefits of community involvement, among government staff and within NGOs or research institutions.

There are great variations in the skills and motivation of community members to undertake any field-based monitoring work, as clerical skills in recording on paper do not necessarily combine with intimate knowledge of local trees and forest locations. As is found all over the world, some people in communities will be good at doing this work, while others will not be. Choosing the right people, training and motivating them, and keeping them interested is the key to scaling these actions up for the use of REDD+.

Within the scientific community, there also remains a good deal of skepticism about whether, and in what circumstances, and in order to collect what kinds of data, local people can be comparable with foresters. There is a need for further rigorous evaluations of these issues and documentation of what works, and why.

CONCLUSION

Community involvement in REDD+ receives much attention in the international negotiations on REDD+ policies but is not widely implemented. Of our review of 50 projects under the CCBA standards, 52% plan to involve communities in monitoring in some way. Although this number has been increasing over time, it remains small and does not truly show commitment from REDD+ project and national implementers to fully involve local communities in this forest management strategy.

A related element of community involvement in REDD+ is the role that community members might play in monitoring on-the-ground activities, including providing reasonably low cost field data from project implementation sites. Involving local communities could contribute to a more just implementation of REDD+. In countries and forest areas where there is a sufficient number of local people capable of measuring trees relative to the task of tree measurement, and where there are sufficient rewards for the time those people would spend on this activity, community-based monitoring approaches could provide useful inputs to national REDD+ programs and the monitoring of forest conservation impacts.

Our findings corroborate previous evidence (Danielsen et al. 2011, Skutsch et al. 2011) that local stakeholders with limited education can monitor forest biomass, and in many circumstances can fulfill the IPCC's highest standards, Tier 3. Whereas remotely gathered data would be Tier 1 or at best Tier 2 using defaults for biomass stock exchange, local-level data at Tier 3 increase the overall quantity of carbon that the state, the communities, or the private sector could claim internationally.

We obtained similar results for forest biomass when measured by communities and professional foresters in 289 vegetation plots in Southeast Asia. Accuracy concerns regarding community-based approaches in monitoring forest biomass can be addressed by modest investments in training and support.

Our data set extends the previously limited evidence base (125 permanent plots censused by both community members and professional monitors) (Danielsen et al. 2011, Skutsch et al. 2011) with 289 new plots censused by both community members and professional monitors, although the data sets of community members and foresters did not completely match. These studies extend available results from Tanzanian miombo and Himalayan oak and pine community forests to several new forest types, terrains, socioeconomic contexts, and land tenure systems. Forest types differed between tropical lowland forests in Indonesia to monsoon forest in Laos and Vietnam and mountain rain forest in China.

Our study was undertaken in areas where the community members had not, prior to this experiment, recorded forest biomass data regularly. Results cover only the first year of measurements of forest biomass by community members and professional foresters. How the learning curve and changes in commitment will affect results in the coming years remains to be seen. From the results of volunteer-based monitoring in industrialized countries, we know that new participants account for most of the variation in observer reliability (Dickinson et al. 2010), as observers gain increased familiarity with protocols, improved identification skills, and increased awareness of where certain species occur over time.

Our work shows that there is no real need for handheld computers to capture data, but not using them means that data entry has to be completed using Excel or another spreadsheet program in a computer upon return from the field surveys in order to convert tree girth data to biomass (and hence to carbon). This process has to be done either by community

Table 4. Identified plot level biases in the measurement of aboveground forest biomass by community members and professional foresters, with notes on possible effects and severity of these biases.

Topic	Bias	Effect	Potential frequency of occurrence	Severity when occurring	Remarks
Tree circumference measurement	Holding thumb under the measuring tape while measuring circumference	Increases circumference measurement	Systematic	Medium	Adds approx. 2 cm depending on size of tree
	For trees on slopes, the observer might not maintain the tape perpendicular to the growth direction of the tree at point of measurement (drooping at the back)	Increases circumference measurement	Systematic	Medium	Adds up to 4 cm depending on size of tree
	Measuring tape sagging on far side of trees too large to reach around	Increases circumference measurement	Occasional	Low	Adds up to 2 cm depending on size of tree
	Not removing liana from trees	Increases circumference measurement	Occasional	Medium	Error proportional to liana size
	Measurement too low above buttresses or other deformity	Increases circumference measurement	Occasional	Medium	Error proportional to tree size
	Estimating (not measuring) large or fluted trees or trees with very high buttresses (> 2 m) because of laziness or need of ladder	Increases or decreases circumference measurement	Occasional	Medium	Can severely bias biomass estimate because it affects mainly large trees
Plot demarcation	Including trees smaller than 94 cm circumference in the 9–15-m circle, the outer ring of the circular plot	Increases the number of trees in the plot	Occasional	Medium	Adds up to 20 Mg biomass per hectare depending on size of tree and wood density
	Change in plot size in steep slope	Decreases or increases the number of trees accounted for	Systematic	High	Decreases or increases total plot size
	Change in plot size due to incorrect plot demarcation	Increases or decreases number of trees in plot	Occasional	Medium	
	Rejection of large trees on the border of the plot	Decreases number of trees in plot	Occasional	High	

members with computer skills or by an IO working with communities. Although we found no people skilled in using Excel in any of the communities we worked in, we still feel that this is the simplest approach possible.

Our data show that community monitoring is not necessarily inferior to monitoring by professional foresters in terms of the quality of the data generated. Community monitoring may also be superior in terms of cost effectiveness because we estimate that the costs of community monitoring will decrease over time whereas the costs of forester measurements will remain similar.

There is a need to develop simple standardized methods that can be used at scale and can feed data to national information systems. The work exists as a few, isolated initiatives so far, and there is a great need to embed within national schemes, obtain policy support (i.e., funds and staff set aside), and establish locally suitable standards in each country (Herold and Skutsch 2011). This will take time.

If these approaches are adopted within the implementation of REDD+, periodic third party verification of the monitoring results will be required. This would need to be built into the design and costs of any REDD+ initiative, whether implemented by communities, the State, or the private sector (Danielsen et al. 2011).

Biases observed at the plot level in the field fell into two categories: (i) measurements of tree circumference, and (ii) number of trees included in plot. To help address these potential biases, we have listed all detected aspects of the potential biases in the two categories in Table 4. One of the biases identified was the systematic change in spherical plot sizes when located on steep slopes. Steep to very steep terrain is where probably most remaining forest in Southeast Asia is found today, and this potential bias needs further attention by researchers.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5464

Acknowledgments:

The work in Southeast Asia was part of the project Impacts of Reducing Emissions from Deforestation and Forest Degradation and Enhancing Carbon Stocks (I-REDD+) funded by the European Community's Seventh Framework Research Programme (http://www.i-redd.eu). The participation of M. K. P. in Indonesia was funded by Swiss Development Cooperation through the ASEAN-Swiss Partnership on Social Forestry and Climate Change. The work on examining CCBA forest carbon projects was funded by the Netherlands Development Organisation and Nordisk Fond for Miljø og Udvikling. We would like to thank M. Arpels, A. Yanosky, J. Bampton, M. Boissiere, M. Brockhaus, T. Blomley, S. Butchart, J.-C. Castella, S. G. Caviglia, T. Clements, J. Durbin, T. Evans, S. Gomez, K. Hergoualc'h, P. Iversen, M. Kallio, Y. von Laer, H. O. Larsen, A. Lhumeau, C. Maharani, O. Mertz, M. Moeliono, Y. Natori, C. Padoch, A. Rafiastanto, V. Salviati, M. Skutsch, T. Sikor, S. Swan, D. Thomas, L. Verchot, T. Whitten, the CCBA project implementers, and about 95 community members and professional foresters in Indonesia, China, Laos, and Vietnam for their input into the conceptualization of, and data gathering for, this paper.

LITERATURE CITED

Acharya, K. P. 2002. Twenty-four years of community forestry in Nepal. International Forestry Review 4(2):149–156. http://dx.doi.org/10.1505/IFOR.4.2.149.17447

Agrawal, A., A. Chhatre, and R. Hardin. 2008. Changing governance of the world's forests. Science 320:1460–1462. http://dx.doi.org/10.1126/science.1155369

Agrawal, A., D. Nepstad, and A. Chhatre. 2011. Reducing emissions from deforestation and forest degradation. Annual Review of Environment and Resources 36:373–396. http://dx.doi.org/10.1146/annurev-environ-042009-094508

Agrawal, A., and E. Ostrom. 2008. Decentralization and community based forestry: learning from experience. Pages 44–67 in E. L. Webb and G. Shivakoti, editors. Decentralization, forests and rural communities: policy outcomes in South and Southeast Asia. SAGE, New Delhi, India.

Andrianandrasana, H. T., J. Randriamahefasoa, J. Durbin, R. E. Lewis, and J. H. Ratsimbazafy. 2005. Participatory ecological monitoring of the Alaotra wetland in Madagascar. Biodiversity and Conservation 14:2757–2774. http://dx.doi.org/10.1007/s10531-005-8413-y

Angelsen, A., D. Boucher, S. Brown, V. Merckx, V., C. Steck, and Z. Darin. 2011. Modalities for REDD+ reference levels: technical and procedural issues. The Meridian Institute, Washington, D.C., USA.

Angelsen, A., M. Brockhaus, M. Kanninen, E. Sills, W. D. Sunderlin, and S. Wertz-Kanounnikoff, editors. 2009. Realising REDD+: national strategy and policy options. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Anon. 2012a. Population data, Nepal. [online] URL: http://www.populationdata.net/index2.php?lang=EN&option=pays&pid=149&nom=nepal

Anon. 2012b. Database. Department of Forest, Ministry of Forests and Soil Conservation, Nepal. [online] URL: http://dof.gov.np/division/community-forest-division/community-forestry

Asner, G. P., G. V. N. Powell, J. Mascaro, D. E. Knapp, J. K. Clark, J. Jacobson, T. Kennedy-Bowdoin, A. Balaji, G. Paez-Acosta, E. Victoria, L. Secada, M. Valqui, and R. F. Hughes. 2010. High-resolution forest carbon stocks and emissions in the Amazon. Proceedings of the National Academy of Sciences USA 107(38):16738–16742. http://dx.doi.org/10.1073/pnas.1004875107

Brockington, D. 2007. Forests, community conservation, and local government performance: the village forest reserves of Tanzania. Society & Natural Resources 20:835–848. http://dx.doi.org/10.1080/08941920701460366

Brown, S. 1997. Estimating biomass and biomass change of tropical forests: a primer. FAO Forestry Paper 134, Food and Agriculture Organization of the United Nations, Rome.

Carter, J., and J. Gronow. 2005. Recent experience in collaborative forest management: a review paper. CIFOR Occasional Paper No. 43. Center for International Forestry Research (CIFOR), Jakarta, Indonesia.

Chhatre, A., and A. Agrawal. 2008. Forest commons and local enforcement. Proceedings of the National Academy of Sciences USA 105(36):13286–13291. http://dx.doi.org/10.1073/pnas.0803399105

Chhatre, A., and A. Agrawal. 2009. Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. Proceedings of the National Academy of Sciences USA 106(42):17667–17670. http://dx.doi.org/10.1073/pnas.0905308106

Clark, W. C., T. P. Tomich, M. van Noordwijk, D. Guston, D. Catacutan, N. M. Dickson, and E. McNie. 2011. Boundary

work for sustainable development: natural resource management at the Consultative Group on International Agricultural Research (CGIAR). *Proceedings of the National Academy of Sciences USA* 10:1073. http://dx.doi.org/10.1073/pnas.0900231108

Climate, Community and Biodiversity Alliance (CCBA). 2008. *Climate, community and biodiversity project design standards*. Second edition. Arlington, Virginia, USA.

Colfer, P. C. J., and D. Capistrano. 2005. *The politics of decentralization: forests, power, and people*. Earthscan, London, UK.

Corbera, E., and H. Schroeder. 2011. Governing and implementing REDD+. *Environmental Science & Policy* 14:89–99. http://dx.doi.org/10.1016/j.envsci.2010.11.002

Dam, P., and E. Trines. 2011. Can carbon compete with the loggers in Papua New Guinea? Pages 158–168 in M. Skutsch, editor. *Community forest monitoring for the carbon market*. Earthscan, London, UK.

Danielsen, F., N. D. Burgess, and A. Balmford, editors. 2005. Monitoring matters: examining the potential of locally-based approaches. *Biodiversity and Conservation* 14:2507–2820. http://dx.doi.org/10.1007/s10531-005-8375-0

Danielsen, F., N. D. Burgess, A. Balmford, P. F. Donald, M. Funder, J. P. Jones, P. Alviola, D. S. Balete, T. Blomley, J. Brashares, B. Child, M. Enghoff, J. Fjeldså, S. Holt, H. Hübertz, A. E. Jensen, P. M. Jensen, J. Massao, M. M. Mendoza, Y. Ngaga, M. K. Poulsen, R. Rueda, M. Sam, T. Skielboe, G. Stuart-Hill, E. Topp-Jørgensen, and D. A. Yonten. 2009. Local participation in natural resource monitoring: a characterization of approaches. *Conservation Biology* 23:31–42. http://dx.doi.org/10.1111/j.1523-1739.2008.01063.x

Danielsen, F., N. D. Burgess, and M. Enghoff. 2012. From global to local in REDD+ MRV: linking community and government approaches. Pages 273–274 in A. Angelsen, editor. *Analysing REDD+ challenges and choices*. Center for International Forestry Research (CIFOR), Jakarta, Indonesia.

Danielsen, F., N. D. Burgess, P. M. Jensen, and P. Pirhofer-Walzl. 2010. Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples involvement. *Journal of Applied Ecology* 47:1166–1168. http://dx.doi.org/10.1111/j.1365-2664.2010.01874.x

Danielsen, F., M. M. Mendoza, A. Tagtag, P. A. Alviola, D. S. Balete, A. E. Jensen, M. Enghoff, and M. K. Poulsen. 2007. Increasing conservation management action by involving local people in natural resource monitoring. *Ambio* 36:566–570. http://dx.doi.org/10.1579/0044-7447(2007)36[566:ICMABI]2.0.CO;2

Danielsen, F., M. D. Skutsch, N. D. Burgess, P. M. Jensen, H. Andrianandrasana, B. Karky, R. Lewis, J. C. Lovett, J. Massao, Y. Ngaga, P. Phartiyal, M. K. Poulsen, S. P. Singh, S. Solis, M. Sørensen, A. Tewari, R. Young, and E. Zahabu. 2011. At the heart of REDD+: a role for local people in monitoring forests? *Conservation Letters* 4:158–167. http://dx.doi.org/10.1111/j.1755-263X.2010.00159.x

Dickinson, J. L., B. Zuckerberg, and D. N. Bonter. 2010. Citizen science as an ecological research tool: challenges and benefits. *Annual Review of Ecology, Evolution, and Systematics* 41:149–172. http://dx.doi.org/10.1146/annurev-ecolsys-102209-144636

Edwards, D. P., B. Fisher, and E. Boyd. 2010. Protecting degraded rainforests: enhancement of forest carbon stocks under REDD+. *Conservation Letters* 3:313–316. http://dx.doi.org/10.1111/j.1755-263X.2010.00143.x

Epple, C., E. Dunning, B. Dickson, and C. Harvey. 2011. *Making biodiversity safeguards for REDD+ work in practice. Developing operational guidelines and identifying capacity requirements*. United Nations Environment Program—World Conservation Monitoring Centre, Cambridge, UK.

Fisher, B., S. L. Lewis, N. D. Burgess, R. E. Malimbwi, P. K. Munishi, R. D. Swetnam, R. K. Turner, S. Willcock, and A. Balmford. 2011. Implementation and opportunity costs of reducing deforestation and forest degradation in Tanzania. *Nature Climate Change* 1:161–164. http://dx.doi.org/10.1038/nclimate1119

Forest Peoples Program (FPP). 2012. *Forest Peoples Program comments on the draft UNREDD FPIC guidelines*. Moreton-in-Marsh, UK. [online] URL http://www.forestpeoples.org/sites/fpp/files/publication/2012/01/unreddfpicsubmissionfinaljan20.pdf

Fry, B. 2011. Community forest monitoring in REDD+: the 'M' in MRV? *Environmental Science and Policy* 14:181–187.

Funder, M., F. Danielsen, Y. Ngaga, M. R. Nielsen, and M. K. Poulsen. *In press*. Reshaping conservation: the social dynamics of participatory monitoring in Tanzania's community-managed forests. *Conservation & Society*.

Gardner, T. A., N. D. Burgess, N. Aguilar-Amuchastegui, J. Barlow, E. Berenguer, T. Clements, F. Danielsen, F. Ferreira, F. Foden, A. C. Lees, M. R. Roman-Cuesta, L. Parry, C. B. Schmitt, N. Strange, S. M. Khan, I. Theilade, and I. C. G. Vieira. 2012. A framework for integrating biodiversity concerns into national REDD+ programmes. *Biological Conservation* 154:61–71. http://dx.doi.org/10.1016/j.biocon.2011.11.018

Ghazoul, J., R. Butler, J. Mateo-Vega, and L. P. Koh. 2010. REDD: a reckoning of environment and development

implications. Trends in Ecology and Evolution 25:396–402. http://dx.doi.org/10.1016/j.tree.2010.03.005

Gibson, C. C., J. T. Williams, and E. Ostrom. 2005. Local enforcement and better forests. World Development 33:273–284. http://dx.doi.org/10.1016/j.worlddev.2004.07.013

GOFC-GOLD. 2010. A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation. GOFC-GOLD Report, version COP 16-1, Alberta, Canada.

Gregersen, H., S. Draper, and D. Elz, editors. 1989. People and trees. The role of social forestry in sustainable development. CAB International, Wallingford, UK.

Hairiah, K., S. Dewi, F. Agus, S. J. Velarde, A. Ekadinata, S. Rahayu, and M. van Noordwijk. 2011a. Measuring carbon stocks across land use systems: a manual. World Agroforestry Centre–ICRAF, South East Asia Regional Office, Bogor, Indonesia.

Hairiah, K., A. Ekadinata, R. R. Sari, and S. Rahayu. 2011b. Pengukuran cadangan karbon dari tingkat lahan ke bentang lahan. Second edition. World Agroforestry Centre–ICRAF, South East Asia Regional Office, Bogor, Indonesia.

Herold, M., and M. Skutsch. 2011. Monitoring, reporting and verification for national REDD + programmes: two proposals. Environmental Research Letters 6(1):014002.

Howell, S. 2012. No rights—no REDD: the credibility gap between intention and execution. Beyond carbon: enabling justice and equity in REDD+ across levels of governance, 23–24 March 2012, St. Anne's College, Oxford, UK. [online] URL http://www.eci.ox.ac.uk/redd/downloads/ppt/3-2-howell.pdf

Jack, B. K., C. Kousky, and K. R. E. Sims. 2008. Designing payments for ecosystem services: lessons from previous experience with incentive-based mechanisms. Proceedings of the National Academy of Sciences USA 105:9465–9470.

Kanel, K. R. 2004. Twenty-five years' of community forestry: contribution to Millennium Development Goals. 4th National Community Forestry Workshop, 4–6 August, 2004, Kathmandu, Nepal. Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

Koleff, P., K. J. Gaston, and J. J. Lennon. 2003. Measuring beta diversity for presence–absence data. Journal of Animal Ecology 72(3):367–382. http://dx.doi.org/10.1046/j.1365-2656.2003.00710.x

Larson, A., D. Barry, G. Dahal, and C. Colfer, editors. 2010. Forests for people: community rights and forest tenure reform. Earthscan, Washington, D.C., USA.

Lopa, D., I. Mwanyoka, G. Jambiya, T. Massoud, P. Harrison, M. Ellis-Jones, T. Blomley, B. Leimona, M. van Noordwijk, and N. D. Burgess. 2012. Towards operational payments for water ecosystem services in Tanzania: a case study from the Uluguru Mountains. Oryx 46:34–44.

Merger, E., M. Dutschke, and L. Verchot. 2011. Options for REDD+ voluntary certification to ensure net GHG benefits, poverty alleviation, sustainable management of forests and biodiversity conservation. Forests 2:550–577. http://dx.doi.org/10.3390/f2020550

Meyfroidt, P., and E. Lambin. 2011. Global forest transition: prospects for an end to deforestation. Annual Review of Environment and Resources 36:343–371. http://dx.doi.org/10.1146/annurev-environ-090710-143732

Mukama, K., I. Mustalahti, and E. Zahabu. 2012. Participatory forest carbon assessment and REDD+: learning from Tanzania. International Journal of Forestry Research 2012:126454.

Nielsen, M. R., and J. F. Lund. 2012. Seeing white elephants? The production and communication of information in a locally-based monitoring system in Tanzania. Conservation & Society 10(1):1–14. http://dx.doi.org/10.4103/0972-4923.92188

Penman, J., M. Gytarsky, T. Hiraishi, T. Krug, D. Kruger, R. Pipatti, L. Buendia, K. Miwa, T. Ngara, K. Tanabe, and F. Wagner, editors. 2003. Good practice guidance for land use, land-use change and forestry. IPCC National Greenhouse Gas Inventories Programme and Institute for Global Environmental Strategies, Kanagawa, Japan. [online] URL http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents

Peters-Guarin, G., and M. K. McCall. 2011. Participatory mapping and monitoring of forest carbon services using freeware: Cyber Tracker and Google Earth. Pages 94–104 in M. Skutsch, editor. Community forest monitoring for the carbon market. Earthscan, London, UK.

Phelps, J., E. L. Webb, and A. Agrawal. 2010. Does REDD+ threaten to recentralize forest governance? Science 328:312–313. http://dx.doi.org/10.1126/science.1187774

Pratihast, A. K., and M. Herold. 2011. Community based monitoring and potential links with national REDD+ MRV. Proceedings of the FCPF workshop – Linking community monitoring with national MRV for REDD+. CIGA-UNAM, Mexico City, Mexico, 12–14 September 2011.

Preacher, K. J. 2001. Calculation for the chi-square test: an interactive calculation tool for chi-square tests of goodness of fit and independence. [online] URL http://www.quantpsy.org/chisq/chisq.htm

Putz, F. E., and K. H. Redford. 2009. Dangers of carbon-based conservation. *Global Environmental Change* 19:400–401. http://dx.doi.org/10.1016/j.gloenvcha.2009.07.005

Rights and Resources. 2010. *The end of the hinterland forests, conflict and climate change*. Rights and Resources Initiative, Centre for People and Forests, Forest Peoples Programme, World Agroforestry Centre, Nairobi, Kenya.

Robledo, C., J. Blaser, S. Byrne, and K. Schmidt. 2008. *Climate change and governance in the forest sector*. Rights and Resources Initiative, Washington, D.C., USA.

Rutishauser E., F. Noor'an, A. Rufi'ie, J. Halperin, and Y. Laumonier. *In press*. Accurate estimates of carbon stocks for carbon credits: how much do allometric models matter? *Ecological Applications*

Schwartzman, S., A. Alencar, and A. P. S. Souza. 2010. Social movements and large scale tropical forest protection on the Amazon frontier: conservation from chaos. *Journal of Environmental Research and Development* 19:174–299.

Sikor, T. 2010. Forest justice: towards a new agenda for forest research and practice? *Journal of Integrative Environmental Sciences* 7(4):245–250. http://dx.doi.org/10.1080/1943815-X.2010.530878

Skutsch, M., editor. 2011. *Community forest monitoring for the carbon market*. Earthscan, London, UK.

Skutsch, M., E. Zahabu, B. Karky, and F. Danielsen. 2011. The costs and reliability of community forestry monitoring. Pages 73–81 in M. Skutsch, editor. *Community forest monitoring for the carbon market*. Earthscan, London, UK.

Strassburg, B. B. N., A. S. L. Rodrigues, M. Gusti, A. Balmford, S. Fritz, M. Obersteiner, R. K. Turner, and T. M. Brooks. 2012. Impacts of incentives to reduce emissions from deforestation on global species extinctions. *Nature Climate Change* 2(5):350–355.

Stuart-Hill, G., R. Diggle, B. Munali, J. Tagg, and D. Ward. 2005. The event book system: a community-based natural resource monitoring system from Namibia. *Biodiversity and Conservation* 14:2611–2631. http://dx.doi.org/10.1007/s10531-005-8391-0

United Nations Framework Convention on Climate Change (UNFCCC). 2011a. *Outcome of the work of the ad hoc working group on long-term cooperative action under the convention*. Draft decision [-/CP.17]. UNFCCC, Bonn, Germany.

United Nations Framework Convention on Climate Change (UNFCCC). 2011b. *Framework Convention on Climate Change, Subsidiary Body for Scientific and Technological Advice (SBSTA), Methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries*. Draft conclusions proposed by the Chair, Thirty-fifth session Durban, 28 November to 3 December 2011, UNFCCC, Bonn, Germany.

UN-REDD. 2011. *UN-REDD guidelines on free, prior and informed consent (FPIC)*. [online] URL http://www.un-redd.org/Launch_of_FPIC_Guidlines/tabid/105976/Default.aspx

van Laerhoven, F. 2010. Governing community forests and the challenge of solving two-level collective action dilemmas —a large-*N* perspective. *Global Environmental Change* 20 (3):539–546. http://dx.doi.org/10.1016/j.gloenvcha.2010.04.005

Venter, O., W. F. Laurance, T. Iwamura, K. A. Wilson, R. A. Fuller, and H. P. Possingham. 2009. Harnessing carbon payments to protect biodiversity. *Science* 326:1368. http://dx.doi.org/10.1126/science.1180289

Verplanke, J., and E. Zahabu. 2009. *A field guide for assessing and monitoring reduced forest degradation and carbon sequestration by local communities*. KTGAL Project, Enschede, Netherlands.

Wagner, F., E. Rutishauser, L. Blanc, and B. Herault. 2010. Effects of plot size and census interval on descriptors of forest structure and dynamics. *Biotropica* 42:664–671. http://dx.doi.org/10.1111/j.1744-7429.2010.00644.x

APPENDIX XIV

Danielsen, F., Jensen, P.M., Burgess, N.D., Altamirano, R., Alviola, P.A., Andrianandrasana, H., Brashares, J.S., Burton, A.C., Coronado, I., Corpuz, N., Enghoff, M., Fjeldså, J., Funder, M., Holt, S., Hübertz, H., Jensen, A.E., Lewis, R., Massao, J., Mendoza, M.M., Ngaga, Y., Pipper, C.B., Poulsen, M.K., Rueda, R.M., Sam, M., Skielboe, T., Sørensen, M. and Young, R. 2014.
A multi-country assessment of tropical resource monitoring by local communities.
BioScience 64: 236–251.

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A Multicountry Assessment of Tropical Resource Monitoring by Local Communities

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The rapid global growth of conservation schemes designed to incentivize local communities to conserve natural resources has placed new importance on biological monitoring to assess whether agreements and targets linked to payments are being met. To evaluate competence in natural resource monitoring, we compared data on status and trends collected independently by local-community members and trained scientists for 63 taxa and five types of resource use in 34 tropical forest sites across four countries over 2.5 years. We hypothesized that the results would vary according to differences in the education and value systems of the monitors. We found that, despite considerable differences in countries, cultures, and the types of natural resources monitored, the community members and the scientists produced similar results for the status of and trends in species and natural resources. Our findings highlight the potential value of locally based natural resource monitoring for conservation decisionmaking across developing countries.

Keywords: participatory monitoring, precision, reliability, sampling accuracy

Global concern over the loss of biodiversity; the potential impacts of climate change; and the unsustainable use of land, forests, and other natural resources has given rise to numerous international conservation initiatives. One group of initiatives offers financial payments to local communities living in biologically rich areas as compensation for their willingness to regulate or reduce their use of globally significant natural resources. Such *payment for ecosystem services* (PES) programs (Jack et al. 2008) include the United Nations Framework Convention on Climate Change Reducing Emissions from Deforestation and Forest Degradation mechanism (UNFCCC 2012) and more local PES schemes—for example, for water (Fisher et al. 2010) or wildlife (Clements et al. 2010). These programs rely on frequent monitoring at multiple scales to facilitate decisionmaking and to assess whether communities have met established conservation benchmarks and have thereby earned financial or other rewards. Whether such monitoring can and should be the domain of local people or professional scientists is the subject of a large and growing debate (e.g., Luzar et al. 2011). In addition, one of the functions of the newly established Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services is to bring different knowledge systems, including indigenous and local knowledge systems, to the science–policy interface (UNEP 2012). Here, we evaluate the potential of locally based monitoring of natural resources for informing conservation decisionmaking and intergovernmental mechanisms by comparing the results of paired local and professional monitoring efforts in forest habitats in four tropical countries.

How did we get here?

Scientists trained in biological sampling design and field data collection techniques are generally expected to collect data on natural resource trends more accurately than do local people, who may lack formal education (Penrose and Call 1995). Local people are also expected to be less objective than are external scientists when they record the status of natural resources, because of vested interests in their use of those resources (figure 1; Root and Alpert 1994). Given such concerns, the ability of participatory environmental monitoring to accurately detect changes in natural resource populations

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doi:10.1093/biosci/biu001 Advance Access publication 19 February 2014

Figure 1. A Miskito community member recording his sightings and signs of mammals and birds during a foot patrol in Nicaragua. Photograph: Sune Holt.

or patterns of resource use has been widely questioned. If monitoring by local communities is inaccurate or biased, it may not be reliable for assessing trends in the natural world, and management interventions may be directed inappropriately (Burton 2012, Nielsen and Lund 2012).

Debates over the types of policy interventions that best protect natural resources contain an emerging consensus that the monitoring of resource status and use is necessary to achieve sustainability (Ostrom and Nagendra 2006, Ostrom 2009). Within this literature, species and habitat monitoring by local communities or external agencies has often been assumed to yield the same results (Coleman and Steed 2009), but little empirical testing of this assumption exists. Other literature suggests that the immense amount of monitoring required to measure natural resource trends around the world will, by necessity, require local monitoring (Sodhi and Ehrlich 2010).

Previous investigations in which the accuracy of natural resource information generated by local communities in developing countries was assessed have been qualitative studies, individual case studies, or limited by small sample sizes (tables 1 and 2). All of the individual case studies and those with small sample sizes have been restricted to small geographical areas. Most have been focused on a comparison of static findings—for example, population density at a single point in time. Few have involved trends over time, which is critical when resource monitoring is intended to inform natural resource management and sustainable use (Jones et al. 2008). From our review, in only eight studies were field data collected by local groups and those collected by external groups from the same areas and at the same time of year compared (tables 1 and 2). Taken together, these previous studies provide cautious support for the idea that monitoring of natural resources by local people can provide accurate data.

How did we study this issue?

To resolve the ongoing uncertainty concerning the role of local communities in natural resource monitoring, we conducted a quantitative comparison of data collected on the status of and trends in selected natural resources by trained scientists and community members across multiple countries. These data were collected simultaneously by the two monitoring groups, which included 7 university-trained scientists and 128 local people, mostly with no more than a primary-school education, over 2.5 years in tropical forests of Madagascar (figure 2), Nicaragua, the Philippines, and Tanzania (figure 3). The three monitoring programs included in our study were locally based, long-running, and formalized schemes used to guide resource management decisions. In these cases, we established parallel, scientist-executed schemes in the same areas. In one country, where no local monitoring scheme existed, one scheme was established in collaboration with the local communities.

Our focus in this study was to compare resource abundance data collected by local community members with those collected by external scientists. Likewise, we focused on the information most relevant to natural resource management decisions, such as the status of and trends in abundance indices. We did not assess the reliability of either group against some base measure.

Our working hypothesis was that measures of the abundance of natural resources would differ when they were assessed by community members and trained scientists. We tested this hypothesis by comparing data from patrols by community members (figure 4) and line-transect surveys by trained scientists along the same or adjacent survey routes in the same forest areas and over the same 3-month period.

What data did we collect?

We collected field data from January 2007 to June 2009 across 34 sites (table 3). The study sites were located opportunistically on the basis of existing locally based forest-monitoring schemes, except in Nicaragua, where we established a local monitoring scheme for the purpose of this study. The area and boundary of each study site was agreed on by the

Table 1. Sampling size of published comparisons of the accuracy of community member– and trained scientist–executed natural resource monitoring in developing countries.

Study	Country	Communities or sites surveyed	Type of data collected	Number of community members	Attribute	Status or trend
Hellier et al. 1999	Mexico	2 communities	Interviews	57	Forest cover and harvested species	Trend[a]
Noss 1999	Central African Republic	1 village	Counts	–	Abundance and density of game species	Status
Gavin and Anderson 2005	Peru	3 communities	Interviews	67 families	Plants and animals harvested	Status
Uychiaoco et al. 2005	The Philippines	8 communities	Counts	–	Reef benthic cover and fish abundance	Status[b]
Lunn and Dearden 2006	Thailand	Villages in 1 national park	Interviews	70	Fish catch and effort	Status
Halme and Bodmer 2007	Peru	1 village	Interviews	26	Forest types	Status
Holck 2008	Tanzania	4 sites in one forest reserve	Counts	16	Forest disturbance	Status
Jones et al. 2008	Madagascar	1 village	Interviews	22 households	Crayfish (*Astacoides*) and firewood collection	Status
Léopold et al. 2009	Fiji	1 customary rights area	Counts	2	Reef fish abundance	Status
Acharya et al. 2009	India	3 1000-meter transects	Counts	4	Bird species richness	Status
Yasué et al. 2010	The Philippines	1 village	Interviews	79	Reef fish abundance	Trend
Mueller et al. 2010	Niger	1 village	Interviews	–	Species richness, diversity and height of grasses and trees	Status
Rist J et al. 2010	Equatorial Guinea	1 village	Interviews and counts	55	Bushmeat hunting catch and effort	Status
Rist L et al. 2010	India	16 villages around a sanctuary	Interviews	47	Mistletoe (*Taxillus tomentosus*) infection	Status
Oldekop et al. 2011	Ecuador	9 communities	Counts	20	Species richness of ferns	Status
Nagendra et al. 2011	Several countries	53 forests	Interviews	–	Densities of trees and shrubs and saplings	Trend[a]

Note: The dashes denote that no data were available. [a]Retrospectively. [b]In two communities, static findings over several years.

scientists and the representatives of the local communities. A *study site* was defined as a specific area of discernible forest or woodland with a size ranging from a few hundred hectares to several thousand hectares and, furthermore, that was important in terms of both its biological resources and its value to local livelihoods.

Representatives of the local communities in the study areas helped us select community participants on the basis of their interest in and experience with forest resources. The community participants included some of the most experienced collectors of forest products in each study site. Most of the community participants had attended only primary school and had a limited ability to read and write; however, in each study site, there was at least one literate participant.

The community participants received training from an intermediary organization once, for 2–3 days per study site, in the recording of forest resources and resource use during forest patrols. In Nicaragua, this training was provided at the beginning of the present study, whereas in the other three countries, this training was provided several years ahead of the study, when the schemes were established (in the Philippines, 9 years earlier; in Tanzania, 5 years earlier; in Madagascar, 3 years earlier). In all of the study sites, however, during the time of the present study, training follow up was performed during visits of 2–3 hours per study site each year, during which the researchers assisted the community participants and obtained copies of the field forms.

The scientists had academic degrees at the master's level or the equivalent in a natural science. They all had at least 10 years of prior field experience in tropical forest surveys.

The community participants obtained no payment for their work, but they were provided meals and snacks, except in three study sites in Tanzania, where they were paid for their labor by the village (the equivalent of US$1– US$2 per day, with funds generated from local user fees) as part of the existing monitoring schemes. The idea was that the time and effort provided by the community members for monitoring should match those that they were already providing in the existing locally based monitoring schemes, which are being sustained with no or very limited external funding because of their utility for local communities' decisionmaking (Danielsen et al. 2010a).

Table 2. Results of published comparisons of the accuracy of community member– and trained scientist–executed natural resource monitoring in developing countries.

Study	Biome	Attribute	Matched time and area[a]	Agreement of community member– with trained scientist–executed surveys
Hellier et al. 1999	Terrestrial	Forest cover and harvested species	No[b]	There was some contradiction with scientist-derived data on vegetation change.
Noss 1999	Terrestrial	Abundance and density of game species	No[c]	For two out of four species, a hunter-based method generated only abundance indices, not density estimates.
Gavin and Anderson 2005	Terrestrial	Plants and animals harvested	No[d]	There was agreement on species harvested but contradiction on quantities.
Uychiaoco et al. 2005	Marine	Reef benthic cover and fish abundance	Partially[e]	One of four community measures of reef benthic cover and fish abundance correlated with the scientists' reports.
Lunn and Dearden 2006	Marine	Fish catch and effort	No[f]	Fishermen reported larger catches and greater effort than the scientists observed.
Halme and Bodmer 2007	Terrestrial	Forest types	Yes	There was close correspondence between forest type classification by communities and floristic classification by botanists.
Holck 2008	Terrestrial	Forest disturbance	Yes	After a few days' training, the local people produced data that matched scientists'.
Jones et al. 2008	Terrestrial and freshwater	Crayfish (*Astacoides*) and firewood collection	Yes	Local reports of quantities, effort, and spatial pattern of harvesting were comparable with the scientists'.
Léopold et al. 2009	Marine	Reef fish abundance	Yes	The local people overestimated fish abundance and provided more variable results than did the scientists.
Acharya et al. 2009	Terrestrial	Bird species richness	Yes	There were strong similarities in bird species recorded.
Yasué et al. 2010	Marine	Reef fish abundance	No[b]	There was a gap between community perceptions and biological survey results on changes in fish abundance, size, and diversity.
Mueller et al. 2010	Terrestrial	Species richness, diversity and height of grasses and trees	No[d]	The community members and the scientists agreed on height and density measures for grasses and trees and on tree species richness but not on herb species richness.
Rist J et al. 2010	Terrestrial	Bushmeat hunting catch and effort	Yes	Community and scientist data matched on catch and effort and the locations of hunting trips.
Rist L et al. 2010	Terrestrial	Mistletoe (*Taxillus tomentosus*)	Yes	Harvesters provided accurate information on infection characteristics and primary host species but were less accurate for secondary host species.
Oldekop et al. 2011	Terrestrial	Species richness of ferns	Yes	There was a strong correlation of species richness estimates between the community members and the scientists.
Nagendra et al. 2011	Terrestrial	Densities of trees and shrubs and saplings	Partially[g]	Qualitative community assessments of changes in tree density were correlated with change determined by the scientists from randomly distributed forest plots.

[a]Surveys undertaken at the same temporal and spatial scales, at the same time (within the same 3-month period) and in the same geographical area. [b]Different scales and different time and area. [c]Different time and area. [d]Different temporal scale and different time. [e]Almost the same area; same scales and same time. [f]Different time. [g]Almost the same temporal scale, different spatial scale, same area.

Prior to the fieldwork, we had asked the community participants to select natural resources and resource-use events that they would like to monitor. We proposed a minimal list: a species of large mammal (more than 5 kilograms [kg]), a species of small mammal (less than 5 kg), a species of bird (figure 5), a type of resource use of animals (figure 6), and a type of resource use of plants (figure 7). On the basis of these criteria, the community members decided on 68 targets to be monitored (tables 4 and 5), which were divided into three classes: birds (39 taxa), mammals (24 taxa), and resource use (e.g., cut bamboo; there were five types of resource use). Most of these resources were of value to the local people.

The community members recorded sightings and signs of natural resources and fire, snares, and other resource use during regular foot patrols in the forest. In Madagascar and Tanzania, at each study site, the community participants carried out patrols two to three times per month; the duration of each patrol was typically 3–6 hours, and they were sometimes up to 14 kilometers long. In Nicaragua and the Philippines, the community members carried out patrols one time during each 3-month period; each patrol had a duration of 2 hours and a length of 2000–2500 meters (m). For safety reasons, the community participants always worked in pairs.

Figure 2. Dry deciduous forest in central western Madagascar. Photograph: Anselme Toto Volahy.

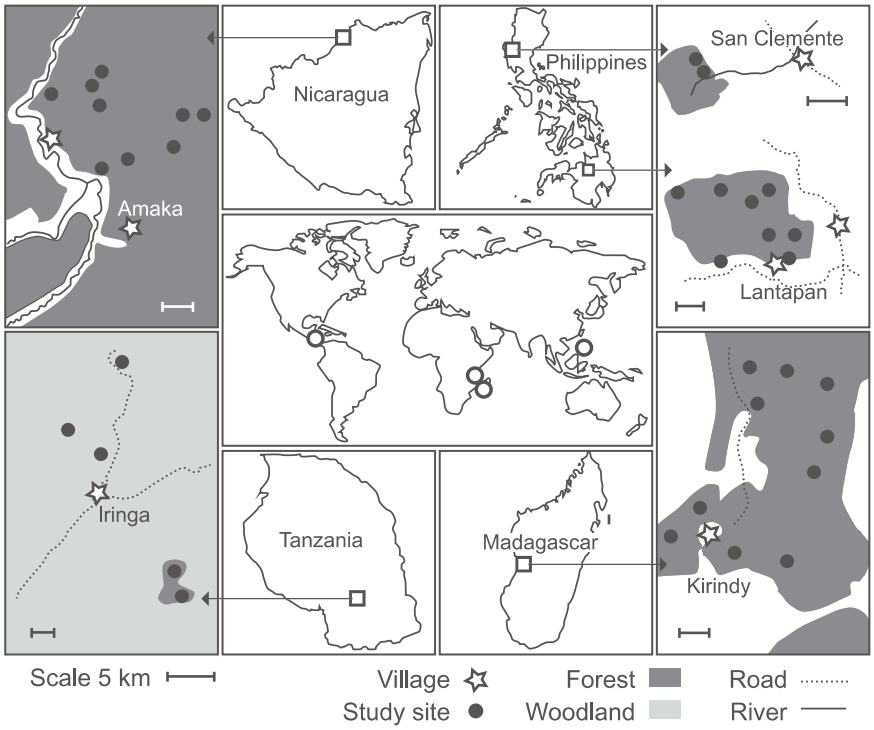

Figure 3. The locations of the 34 tropical forest study sites in Madagascar, Nicaragua, the Philippines, and Tanzania. Abbreviation: km, kilometers.

In all four countries, the scientists carried out surveys of natural resources and resource use along fixed routes within the same forest or woodland study sites, using a variable-distance line-transect method (adapted from Buckland et al. 1993). One or two transect routes were surveyed by each scientist once during each 3-month period in each study site. The length of the transect routes was 2000–2500 m. The speed of walking was kept constant at about 1 kilometer per hour. This speed allowed brief stops when animal vocalizations and signs of resource use were detected. For each resource or resource-use contact, the scientists sought to record the name of the species or resource-use event and the number of individuals or resource-use events. The scientists attempted to avoid counting the same individual twice. In order to minimize biases caused by differing detectability, all of their surveys were made during optimal conditions (i.e., between 6:00 and 9:00 a.m., during clear, dry weather). All surveys of a study site were undertaken by the same scientist working alone.

Both the community participants and the scientists recorded all of their observations, independent of the distance from the survey routes. Likewise, both direct sightings and indirect evidence (e.g., calls, tracks, scat, burrows) were recorded. For resources that occurred in clusters (groups), the cluster size was estimated. Moving resources (e.g., birds in flight) were also recorded.

We did not standardize the shape, length, or location of the community member survey routes among the countries, because all of the local schemes, except in Nicaragua, were based on community monitoring systems that existed prior to this study. In the Philippines and Nicaragua, fixed routes were surveyed inside the forest (along existing narrow forest trails), and the scientists surveyed the same routes but on separate days. In Tanzania, the existing community patrol routes varied from survey to survey, dependent on where the monitors expected to find cut trees or illegal uses of forest resources. In Madagascar, the existing patrol routes were located along the forest boundary. In these countries, the scientists established survey routes independent of the existing system of trails inside the woodland or forest. These survey routes were meant to include representative habitats for the study sites and were cut in a straight line in each study site, regardless of logging roads, light gaps, and so on. We did not force the scientists to survey the same routes as those of the community members in the two countries with more variable routes (Tanzania and Madagascar), because we sought a more realistic comparison between the scientists' standardized, fixed-route surveys and

*Figure 4. Community members monitoring miombo (*Brachystegia*-dominated) woodland resources in Tanzania. Photograph: Michael K. Poulsen.*

the different, country-specific approaches to locally based natural resource monitoring.

In Nicaragua and Tanzania, the community member and scientist surveys were a few days apart (Nicaragua, mean [*M*] = 11.1 days, standard error [SE] = 1.2; Tanzania, *M* = 6.32 days, SE = 8.9), whereas in the Philippines and Madagascar, there were longer gaps in time between the surveys (Philippines, *M* = 13.5 days, SE = 15.9; Madagascar, *M* = 47.5 days, SE = 8.7).

How did we undertake the analysis?

Our study was essentially a double-observation test, which did not include controls or other experimental interventions. It was not known whether the trained scientists or the community members recorded true abundance; indeed, it is unlikely that either measurement of abundance is without error. Given the variation inherent in sampling natural resource abundance, we chose an analytical approach designed to effectively test the hypothesis that community members and trained scientists are equally good monitors. Specifically, we organized the observations in paired time series, excluded time series for rare resources detected inconsistently, and used a generalized linear model that is particularly sensitive to differences between scientists and community members.

Our time series consisted of the number of counted individuals of particular natural resources and events of resource use per hour of effort in each 3-month period (a quarter of a year) within a specific site. When the locals sampled several times within a given quarter, the sum of individuals recorded for all surveys within the quarter divided by the number of hours of effort was used as an observation for the given quarter. Quarterly sample units were chosen because the records include one trained scientists' survey at each site in each 3-month period.

We excluded time series for rare resources that were reported by only one of the observer groups. We considered these resources to occur below a detection threshold for reliable reporting, given the level of survey effort typical of the monitoring schemes. Counts of such rare resources tend to have a high standard error relative to the mean, which increases the noise:effect ratio and thereby decreases the probability of rejecting the null hypothesis (i.e., increases the probability of a type II error). Furthermore, agreement on the absence of very rare species could lead to an artificially high correlation between the two groups of monitors.

Table 3. Study areas, their levels of disturbance, and the type of vegetation studied.

Country	Location	Number of study sites	Vegetation	Altitude (in meters above sea level)	Disturbance level
Madagascar	Menabe Antimena protected area	10	Dry, deciduous forest	25–100	Most of the area is only marginally disturbed, but the periphery of the reserve is moderately to severely degraded
Nicaragua	Bosawas Biosphere Reserve	9	Wet, dipterocarp forest	180–360	Moderately degraded
Philippines	Mount Kitanglad Range Natural Park, Bukidnon, Mindanao	8	Wet, dipterocarp forest	850–1700	Two sites largely undisturbed, six sites moderately to severely degraded
Philippines	Mount Manleluag, Pangasinan, Luzon	2	Wet, dipterocarp forest	200–350	Moderately to severely degraded
Tanzania	Forest reserves in Iringa and Kilolo Districts	3	Miombo woodland	1050–1750	Largely sustainably used or moderately to severely degraded from unsustainable cutting of wood for charcoal
Tanzania	Forest reserves in Iringa and Kilolo Districts	2	Montane evergreen forest	1750–2100	Marginally disturbed except for game poaching

Figure 5. Scale-feathered malkoha (*Dasylophus cumingi*) in the Philippines. Photograph: Martin Lindop.

Figure 6. A hunter disentangling a snared blue duiker (*Philantomba monticola*) in Tanzania. Photograph: Michael K. Poulsen.

Finally, we felt that including rare species could bias the results simply because the community members had spent more survey effort in our comparisons, not because they were (necessarily) more adept at detecting rare species than were the trained scientists (see the supplemental material).

Records of natural resources occurring at multiple sites were considered independent observations, even if it could be expected that the given individual resource may have belonged to the same population. Our unit of observation was quarterly summed counts per hour of effort, and one observation was composed of a series of quarterly effort-adjusted counts of a specific resource at a specific site. This condensation of the data generated 600 time series (300 each from the community members and the trained scientists) spanning 3–10 quarters (i.e., 9–30 months; M = 7.13 quarters, SE = 0.10). A total of 55 time series originated from Nicaragua, 85 were from Madagascar, 125 were from the Philippines, and 35 were from Tanzania.

From each time series, we calculated the mean, the standard deviation, and the coefficient of variation from effort-adjusted counts across quarterly time series (see table 6 for an example). Trends in the abundance of resources or resource use over time were assessed by linear regression to provide a conservative estimate of the trends. Relative trends were calculated by dividing the trends by the mean count across quarters (i.e., the mean number of individuals recorded per hour) for the given resource or resource-use event. Finally, Pearson's correlation coefficient was calculated for each paired time series. The data are provided in supplemental data set S1 for the purpose of replicating and building on this work.

The observations were analyzed as paired data, because analyzing paired data increases the chances of detecting systematic differences among the observers. For example, if the community members recorded counts per hour of 1, 2, 3, 4, and 5 and the trained scientists recorded 2, 3, 4, 5, and 6, the derived means would be 3 and 4 (SEs = 0.7), these would not be significantly different when they were assessed as independent samples, but by pairing the data, it would be found that the trained scientists systematically found higher counts per hour than did the community members (exactly one more in each pair). When pairing was noted as significant, it means that the community members' and the trained scientists' counts per hour were highly and positively correlated.

The paired records were evaluated in a generalized linear model, which—in a single model—was able to assess both the correlation between the observers and whether their observations were significantly different. When no significant differences were found between the two types of observers, we assumed that the community members' and the trained scientists' methods were equally effective within the limitations

Figure 7. Trees cut with axes for charcoal production in Tanzania. Photograph: Michael K. Poulsen.

imposed by transect observations (e.g., Plumptre 2000). For further details, see the supplemental material.

We performed analyses of variance (ANOVAs) to determine main effects and Bonferroni-corrected *t*-tests for *post hoc* comparisons ($\alpha = .05$). We checked all of the model fits graphically by means of residual plots and Q–Q plots. The estimated changes are presented with 95% confidence intervals, and the estimated relative changes are presented as percentages accompanied by 95% confidence intervals (95% CI) calculated on a log scale and back transformed. All analyses were made using SAS (version 9.1, SAS institute, Cary, North Carolina).

What did we find?

A total of 24,881 hours of monitoring by the community members (19,183 hours) and the trained scientists (5698 hours) yielded 5804 paired records between the two groups for the same natural resource or resource-use activity at the same site during the same 3-month period.

Assessment of natural resource status. Paired mean counts per hour by the community members and the trained scientists differed significantly (test for heterogeneity between pairs, $p < .001$). There was also a highly significant effect of the type of observer on the mean count per hour ($p < .001$), with the community members producing a 53% (95% CI = 43–62) lower count per hour than did the scientists. When the scientists surveyed the same fixed routes inside the forest as did the community members (i.e., in Nicaragua and the Philippines), the two groups of observers obtained comparable mean counts per hour (figure 8a, table 7a, 7b; the differences were 4.8% for Nicaragua and 29.8% for the Philippines). When the scientists surveyed fixed routes inside the forest and the community members surveyed along the forest boundary (i.e., in Madagascar) or when the community members surveyed along existing trails and varied their survey routes over time, dependent on where they expected to find resources (i.e., in Tanzania), the scientists' mean counts per hour were 358% (Madagascar) and 452% (Tanzania) higher than those of the community members (figure 8a, table 7a, 7b).

In terms of the precision of the observed indices of abundance of natural resources, we analyzed the absolute precision (i.e., the standard deviation) and the relative precision (i.e., the coefficient of variation). With the present effort, the standard deviation of the counts per hour (figure 8b) showed no significant effect of observer ($p = .22$). Within a given pair of observers, the standard deviation for the community members was 12% (95% CI = –8 to 28) lower than that for the trained scientist observers. In addition, there was a highly significant effect of pairing (test for heterogeneity between pairs, $p < .001$) that could not be explained by differences in country and class, which suggests that, in cases in which the scientists provided highly variable counts per hour, so did the community members. In terms of coefficients of variation, as a further measure of precision, there was no significant difference in the mean counts per hour between groups ($p = .14$). Within a given pair of observers, the expected coefficient of variation was estimated to be 7% (95% CI = –2 to 18) higher among the community members than that among the scientist observers. As was expected, there was a significant effect of pairing (test for heterogeneity between pairs, $p < .001$). Therefore, the variation in the observations of the pairs of community members and scientists was substantial—or, equivalently, the observations within pairs of community members and scientists were positively correlated.

Assessment of trends in natural resources. Our comparison of trends in the counts per hour by the community members and by the trained scientists revealed that variation in the trends over time was associated with the observer type ($p = .02$). Regarding the differences between observers, the scientists recorded, on average, 11% (95% CI = 5–18) greater rates of decline than did the community members.

Large differences in relative trends were observed between classes of resources (table 8a, 8b). The community members found mean relative changes in indices of resource abundance that closely matched those found by the trained scientists (figure 9). Moreover, considerable differences in relative trends were observed among countries. The community members and the trained scientists reported comparable mean relative changes in natural resources in Madagascar, Nicaragua, and the Philippines, whereas their results were less comparable in Tanzania (table 7a, 7b).

Table 4. Birds recorded by the community members and trained scientists between 2007 and 2009 and the number of paired observations of each species (180 total).

Country	Taxon	Common name	*n*
Madagascar	*Coua coquereli*	Coquerel's coua	10
	Coua cristata	Crested coua	10
	Coua gigas	Giant coua	10
	Lophotibis cristata	Madagascar crested ibis	2
	Mesitornis variegatus	White-breasted mesite	8
Nicaragua	*Ara ambiguus*	Great green macaw	9
	Crax rubra	Great curassow	4
	Pteroglossus torquatus	Collared aracari	8
	Ramphastos sulfuratus	Keel-billed toucan	9
	Ramphastos swainsonii	Chestnut-mandibled toucan	9
Philippines	*Accipitridae* spp.	Raptor spp.	2
	Basilornis mirandus	Apo myna	1
	Buceros hydrocorax, Aceros leucocephalus	Rufous hornbill, writhed hornbill	3
	Centropus viridis	Philippine coucal	1
	Chrysocolaptes lucidus	Greater flameback	1
	Dasylophus cumingi	Scale-feathered malkoha	1
	Dasylophus superciliosus	Rough-crested malkoha	1
	Dicrurus balicassius	Balicassiao	2
	Dryocopus javensis	White-bellied woodpecker	5
	Ducula spp.	Imperial pigeon spp.	4
	Gallus gallus	Red junglefowl	8
	Haliastur indus	Brahminy kite	3
	Loriculus philippensis, Bolbopsittacus lunulatus	Philippine hanging parrot, guaiabero	7
	Macropygia tenuirostris	Philippine cuckoo-dove	8
	Mulleripicus funebris	Sooty woodpecker	1
	Oriolus chinensis	Black-naped oriole	1
	Other *Columbidae* spp.	Other pigeons or doves	10
	Penelopides affinis	Mindanao tarictic hornbill	5
	Penelopides manillae	Luzon tarictic hornbill	2
	Phapitreron leucotis, Phapitreron amethystinus	White-eared brown dove, amethyst brown dove	10
	Picidae spp.	Woodpecker spp.	2
	Prioniturus spp.	Racket-tail spp.	7
	Sarcops calvus	Coleto	1
	Scolopax bukidnonensis	Bukidnon woodcock	2
	Spilornis holospilus	Philippine serpent eagle	4
	Trichoglossus johnstoniae	Mindanao lorikeet	1
Tanzania	*Numida meleagris*	Helmeted guineafowl	3
	Pternistis afer	Red-necked spurfowl	3
	Tauraco livingstonii	Livingstone's turaco	2

Note: Each paired observation represents a time series of parallel records encompassing at least three sequential quarterly registrations of one resource or resource-use event at one site by community members and trained scientists.

The results show that the relative change in mean counts per hour between pairs varied significantly (test for heterogeneity between pairs, $p < .001$), which may again be thought of as a positive correlation between observations from within pairs of community members and scientists. There was also a significant effect of the type of observer ($p = .02$). Within a given pair of observers, the difference was 6% (95% CI = 1–11). When we omitted the data from Tanzania, where the community members varied their survey route from patrol to patrol, the effect of observer was no

Table 5. Mammal species and resource-use events recorded by community members and trained scientists between 2007 and 2009 and the number of paired observations of each.

Country	Species or resource use	Common species name	Number of observations
Madagascar	*Eulemur rufus*	Red-fronted lemur	6
	Hypogeomys antimena	Giant jumping rat (votsovotsa)	5
	Lepilemur ruficaudatus	Red-tailed sportive lemur	7
	Microcebus murinus	Gray mouse lemur	3
	Mungotictis decemlineata	Narrow-striped mongoose	7
	Propithecus verreauxi	Verreaux's sifaka	9
	Cut trees		5
	New active path		3
Nicaragua	*Cuniculus paca*	Lowland paca	4
	Dasypus novemcinctus	Nine-banded armadillo	5
	Mazama temama	Central American red brocket	4
	Odocoileus virginianus	White-tailed deer	3
Philippines	*Macaca fascicularis*	Crab-eating macaque	3
	Paradoxurus hermaphroditus, Viverra tangalunga	Asian palm civet, Malayan civet	6
	Podogymnura truei	Mindanao gymnure	3
	Rusa marianna	Philippine deer	3
	Sus philippensis	Philippine warty pig	7
	Cut bamboo		1
	Cut trees		5
	Fire		2
	Hunting		2
Tanzania	*Cephalophus natalensis harveyi*	Harvey's duiker	2
	Colobus spp.	Udzungwa red colobus, Angola colobus	2
	Dendrohyrax spp. *and Heterohyrax brucei*	Tree and rock hyrax spp.	1
	Loxodonta africana	African bush elephant	1
	Madoqua kirkii	Kirk's dikdik	3
	Philantomba monticola, Neotragus moschatus	Blue duiker, Suni	1
	Potamochoerus larvatus	Bushpig	3
	Sylvicapra grimmia	Bush duiker	3
	Tragelaphus strepsiceros	Greater kudu	2
	Cut trees		3
	Fire		3
	Hunting		3
Total	Species		93
	Resource use		27

Note: Each paired observation represents a time series of parallel records encompassing at least three sequential quarterly registrations of one resource or resource-use event at one site by community members and trained scientists.

longer significant ($p = .06$). A linear regression of each natural resource in those countries in which fixed survey routes were used (i.e., Madagascar, Nicaragua, the Philippines) suggests that the trained scientist trends could be accurately predicted from the community member trends, such that the community member trend was the trained scientists trend multiplied by 0.82 (± 0.15) minus 0.01 (± 0.02) ($R^2 = .81$, $p = .002$, $n = 8$). The relationship was therefore close to a one-to-one correlation for all natural resources in the three countries (figure 10).

In natural ecosystems, resource abundance may not show simple linear declines or increases but, rather, is more likely to fluctuate over time. We therefore also evaluated the Pearson correlation coefficient for paired time series on the quarterly counts per hour to assess the correlation of relative variation in resource abundance indices over time. The variation over time detected by the community members and the trained scientists was generally positively correlated (table 8b), both for the individual classes of birds, mammals, and resource use types and for the overall data set.

Table 6. Example of calculations based on a hypothetical time series of parallel records of sequential quarterly registrations of one resource or resource-use event at one site.

		Number of individuals per hour				Independent variable for statistical analysis					
Paired set of records	Observer	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Mean number of individuals per hour	Standard deviation	Absolute trend in relative abundance	Coefficient of variation	Relative trend in abundance index	Pearson's correlation coefficient
1	Community member	15	7	9	4	8.75	4.65	–3.10	0.53	–0.35	.80
	Trained scientist	12	5	6	7	7.50	3.11	–1.40	0.41	–0.19	
2	Community member	2	0	4	0	1.50	1.91	–0.20	1.28	–0.13	.00
	Trained scientist	9	1	0	2	3.00	4.08	–2.20	1.36	–0.73	

The within-pair Pearson correlation was significantly affected by both country (p = .005) and class (p = .02). The highest positive average Pearson correlation was found for resource use (r = .27, SE = 0.10), and the lowest was for birds (r = .07, SE = 0.03), whereas that for mammals was in between (r = .17, SE = 0.05; table 8b).

In terms of countries (table 7b), the highest correlation in relative changes in resource abundance indices over time was found for Nicaragua and Tanzania, where the community members' and the scientists' surveys were only a few days apart. The lowest correlation was found for Madagascar, where there was more than a month between the community members' and the scientists' surveys. In between were the Philippines, where the community members' and the scientists' surveys were almost 2 weeks apart.

What do our findings mean?

Our findings suggest that, in tropical forest habitats in developing countries, community members with little or no formal scientific education, who have decided which natural resources should be monitored, can generate records of abundance estimates, relative trends, and the variation over time of natural resources and resource uses that are very similar to those of trained scientists. We found the greatest match in results between the two groups of observers when they surveyed the same route (i.e., Nicaragua, the Philippines) with short time intervals between their surveys (i.e., Nicaragua). We found the least correspondence in results when the community members varied their survey routes among patrols (i.e., Tanzania). We also found matches in relative trends over time but no match in static abundance estimates when the scientists surveyed forest routes and the community members surveyed forest-boundary routes and when there were long time gaps separating the scientist and the community member surveys (i.e., Madagascar). When there were only small differences in the route, area, and time of the surveys by the community members and the trained scientists, the groups produced similar estimates.

The large reduction in resource use recorded during our study (a 22%–30% decline recorded by both the community members and the trained scientists over 1.5 years; figure 9, table 8a, 8b) might be due to a patrol effect of the monitoring: This is either a real reduction in resource use in the study sites or a relocation of resource extraction away from the areas monitored by the communities and scientists as resource users sought to avoid the surveyors.

Our findings on the consistency of the community member counts of resource abundance and trends relative to those of the trained scientists concur with previous studies in the forested habitats of developing countries in which there were no differences in scale, place, or the time of the survey effort between the community members and the scientists (n = 7 studies; tables 1 and 2). Terrestrial studies in which contradictions were reported between community members and scientists had mismatches between the temporal (three studies) and spatial (one study) scales, the timing (four studies), or the geographical area (two studies), which might have influenced these comparisons.

Several factors probably contributed to the correspondence of observations between the community members and the trained scientists in our study. The community members know their forests intimately from years of experience as forest users. Except in Nicaragua, the community members had recorded data regularly over several years, so there would be no learning curve, which accounts for much of the variability in volunteer-based monitoring in industrialized countries (Dickinson et al. 2010). Since the community members' role was to make direct counts, the scheme is not susceptible to changing human perceptions of trends. The patrol records approach is simple and compatible with community members' daily routines for collecting forest products.

How representative are our findings?

We looked at resources of interest to local people. The community members who performed the surveys used forest resources on a weekly basis, and they decided which resources

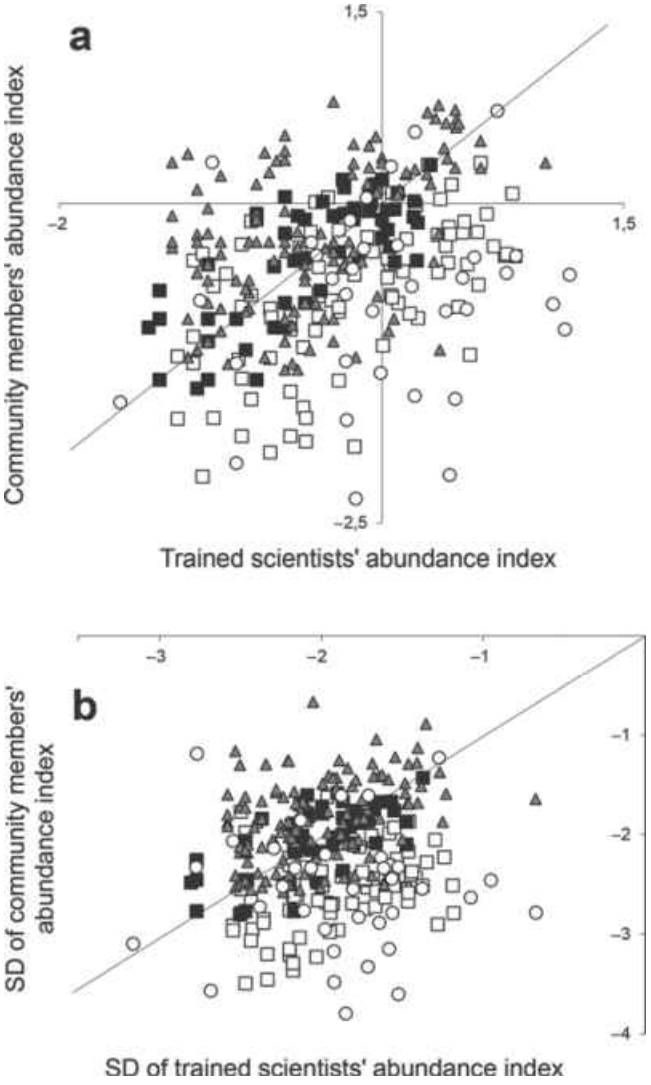

Figure 8. Relationship between the community members' and scientists' (a) indexes of abundance of 68 forest resources and forest uses and (b) the standard deviations (SD) of those measures recorded between 2007 and 2009 at 34 sites in Madagascar (the white squares), Nicaragua (the black squares), the Philippines (the triangles), and Tanzania (the circles) (N = 300 pairs of observations) Note the log_{10} scales. Each point in the graphs represents a time series of records based on the means of effort-corrected quarterly registrations of one resource or resource-use event at one site by community members (y-axis) and trained scientists (x-axis). The diagonal line represents y = x.

to monitor (figure 11). We do not know whether the results would be the same if the scientists had chosen the resources to be monitored. For instance, dung beetles (Coleoptera: Scarabaeinae), which have been shown in empirical studies (Gardner et al. 2008) to be a high-performance indicator for the quality of a tropical forest, may mobilize less enthusiasm among village recorders, but, given our encouraging results across varying biological and socioeconomic contexts across the globe, we believe that these findings are representative for community-based patrol record sampling in tropical forests and savanna woodlands. This is particularly true when the community members are motivated by some training and by clear links to their livelihoods.

Our main comparison was between community members' patrol records and trained scientists' line transects. The line-transect method is recognized to have weaknesses (e.g., Gale et al. 2009) for capturing true resource abundance density and trends. Moreover, other factors, such as the selection of the survey routes, the probability of the detection of resources, and the ease of observing different taxa, may affect our ability to assess trends (Yoccoz et al. 2001).

Our goal was to test whether community members and trained scientists would record similar resource trends, and line transects are the scientific method closest to the community members' patrol system. Moreover, the line-transect method is fairly simple, inexpensive, and widely used by scientists for monitoring natural resources in tropical forests (Peres 1999, Luzar et al. 2011). Other scientific methods (e.g., mark and recapture, point–count methods, territory mapping, camera trapping; Bibby et al. 2000, Burton 2012) would have introduced additional biases and would probably have resulted in a mismatch between the taxa that could be recorded by the scientists and those recorded by the community members.

What is the societal relevance?

Our findings are relevant to ongoing debates on the best ways to monitor natural resources and the potential role of local communities in such monitoring (Chhatre and Agrawal 2009). Across the developing world, decisionmaking has been decentralized to operational levels of management, including to local communities (Agrawal et al. 2008). Therefore, monitoring management outcomes at the local level becomes vital. Moreover, involving community members in resource monitoring helps link that resource monitoring to decisionmaking at the operational level of resource management (Danielsen et al. 2010b) and, therefore, has the potential to become a major contributor to global conservation strategies. This is particularly relevant as the world struggles with linking environmental performance to payment schemes, bringing indigenous and local knowledge systems into the science–policy interface (UNEP 2012), and monitoring basic issues of natural resource change.

Locally based natural resource monitoring has been demonstrated to be suitable for monitoring organisms or phenomena that are meaningful for community members—for example, as a source of food or income or with cultural or spiritual value. However, if the aim is to monitor attributes that are not relevant from the local perspective, locally based natural resource monitoring may not be suitable. This is important to consider for any locally based monitoring scheme.

In the present study, there was no conflict over resources in any of the areas studied. In situations in which an abundance of resources may condition quotas or financial payments

Table 7a. Measures of relative abundance and trends recorded by community members and trained scientists between 2007 and 2009 (N = 300 pairs of observations).

	Madagascar (*n* = 85)				Nicaragua (*n* = 55)				Philippines (*n* = 125)				Tanzania (*n* = 35)			
	Community members		Trained scientists		Community members		Trained scientists		Community members		Trained scientists		Community members		Trained scientists	
Measure	Mean (*M*)	Standard error (SE)	*M*	SE	*M*	SE	*M*	SE	*M*	SE	*M*	SE	*M*	SE	*M*	SE
Number of individuals per hour	0.38	0.05	1.36	0.18	0.63	0.06	0.60	0.07	1.14	0.12	0.80	0.11	0.58	0.19	2.62	0.63
Absolute trend in relative abundance	–0.02	0.01	–0.02	0.03	–0.05	0.02	–0.09	0.02	–0.01	0.03	–0.01	0.03	–0.05	0.05	–0.46	0.18
R^2 of absolute trend	.29	.02	.16	.02	.31	.03	.27	.03	.17	.01	.17	.02	.42	.06	.61	.06
Relative trend in abundance index	–0.06	0.03	–0.02	0.03	–0.12	0.04	–0.14	0.05	–0.03	0.03	–0.07	0.03	0.07	0.10	–0.19	0.09
Standard deviation	4.2×10^{-3}	4.4×10^{-4}	0.02	1.7×10^{-3}	0.01	9.9×10^{-4}	0.01	1.2×10^{-3}	0.02	2.3×10^{-3}	0.01	1.9×10^{-3}	0.01	2.5×10^{-3}	0.03	0.01
Coefficient of variation	1.12	0.09	1.48	0.09	1.40	0.08	1.62	0.09	1.68	0.07	1.67	0.07	1.05	0.09	0.84	0.07

Table 7b. Mean Pearson correlations for paired time series of data and the number of observations in each paired series of observations in each country.

	Madagascar		Nicaragua		Philippines		Tanzania	
Measure	Mean (*M*)	Standard error (SE)	*M*	SE	*M*	SE	*M*	SE
Pearson's correlation coefficient	.06	0.05	.30	0.07	.07	0.04	.13	0.12
Number of observations per series	7.95	0.12	6.18	0.07	7.96	0.15	3.71	0.08

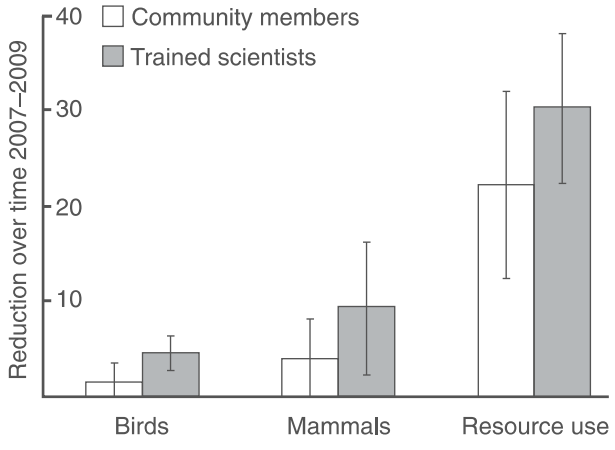

Figure 9. Relative abundance (as the reduction percentage) of 68 forest resources and forest uses recorded by community members (white) and trained scientists (gray) between 2007 and 2009 at 34 sites in Madagascar, Nicaragua, the Philippines, and Tanzania. All of the trends are negative, and the y-axis is therefore inverted (N = 300 pairs of observations; each paired observation represents a time series of parallel records of sequential quarterly registrations of one resource or resource-use event at one site by community members and trained scientists). The error bars represent the standard error.

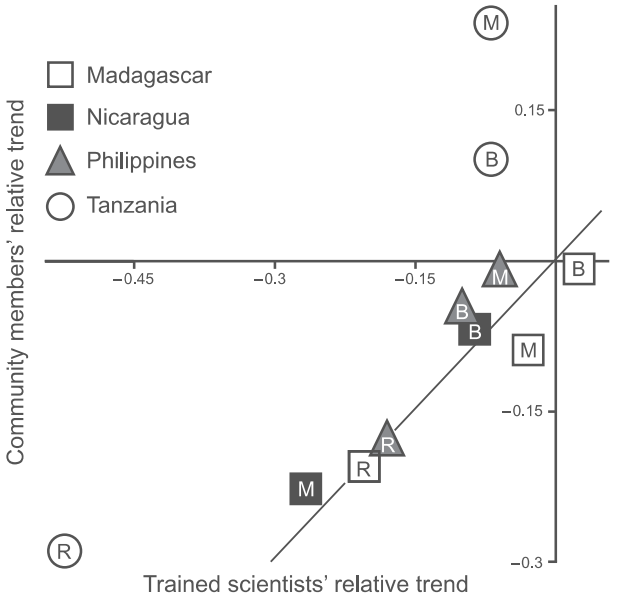

Figure 10. Relative abundance of 68 forest resources and forest uses recorded by community members and trained scientists between 2007 and 2009 at 34 sites in Madagascar, Nicaragua, the Philippines, and Tanzania (N = 300 pairs of observations). The diagonal line represents y = x. Abbreviations: B, birds; M, mammals; R, resource use.

Table 8a. Measures of relative abundance and trend for birds, mammals, and resource uses recorded by community members and trained scientists between 2007 and 2009 (N = 300 pairs of observations).

	Birds (n = 180)				Mammals (n = 93)				Resource use (n = 27)			
	Community members		Trained scientists		Community members		Trained scientists		Community members		Trained scientists	
Measure	Mean (M)	Standard error (SE)	M	SE	M	SE	M	SE	M	SE	M	SE
Number of individuals per hour	0.98	0.09	0.99	0.09	0.42	0.07	1.54	0.28	0.54	0.23	0.72	0.20
Absolute trend in relative abundance	–0.02	0.02	–0.04	0.02	0.01	0.01	–0.09	0.07	–0.10	0.05	–0.29	0.11
R^2 of absolute trend	.22	.02	.20	.02	.32	.03	.25	.03	.31	.05	.43	.06
Relative trend in abundance index	–0.01	0.02	–0.05	0.02	–0.04	0.04	–0.09	0.04	–0.22	0.10	–0.30	0.08
Standard deviation	0.02	1.7×10^{-3}	0.02	9.5×10^{-4}	0.01	9.4×10^{-4}	0.02	3.5×10^{-3}	0.01	2.4×10^{-3}	0.01	2.8×10^{-3}
Coefficient of variation	1.31	0.06	1.47	0.06	1.41	0.08	1.58	0.09	1.89	0.16	1.53	0.14

Table 8b. Mean Pearson correlations for paired time series of data and the number of observations in each paired series of observations for each observation type.

	Birds		Mammals		Resource use	
Measure	Mean (M)	Standard error (SE)	M	SE	M	SE
Pearson's correlation coefficient	.07	0.03	.17	0.05	.27	0.10
Number of observations per series	7.42	0.13	6.89	0.21	6.07	0.38

Figure 11. Miskito community members in Nicaragua selecting the mammal species they would like to monitor. Photograph: Sune Holt.

to communities, the local communities may have an incentive to report false positive trends in those natural resources so that they can continue to harvest the resources or to be paid, even though the resources may actually be declining. Periodic triangulation of the monitoring results will therefore be required, but this is not different from any well-designed natural resource management initiative, whether the monitoring is implemented by communities, the government, or the private sector (Danielsen et al. 2011). Triangulation could be based on random spot checks in which a subset of the area is resampled using other monitors or other field methods (e.g., remote sensing of forest cover). It could also be combined with a statistical analysis of the community-based data to search for anomalies or trends that are beyond the normal or expected range.

Here, we have shown that local people and trained scientists can be equally good at collecting data and, therefore, that local communities can play this role in monitoring if schemes are organized to facilitate their engagement.

Acknowledgments

We thank the participants in the Monitoring Matters: A Comparative Analysis of Innovative Approaches program, who have undertaken fieldwork in arduous and difficult conditions. The research was funded by Danida grant no. 104. Dan.8-1203, and further financial contributions have been made by the University of Copenhagen, the World Wildlife Fund, and the institutions of all of the participating authors.

Supplemental material

The supplemental material is available online at *http://bioscience.oxfordjournals.org/lookup/suppl/doi:10.1093/biosci/biu001/-/DC1*.

References cited

Acharya BK, Chettri B, Vijayan L. 2009. Indigenous knowledge of *Lepcha* community for monitoring and conservation of birds. Indian Journal of Traditional Knowledge 8: 65–69.

Agrawal A, Chhatre A, Hardin R. 2008. Changing governance of the world's forests. Science 320: 1460–1462.

Bibby CJ, Burgess ND, Hill DA, Mustoe SH. 2000. Bird Census Techniques, 2nd ed. Academic Press.

Buckland ST, Anderson DR, Burnham KP, Laake JL. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall.

Burton AC. 2012. Critical evaluation of a long-term, locally-based wildlife monitoring program in West Africa. Biodiversity and Conservation 21: 3079–3094.

Chhatre A, Agrawal A. 2009. Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. Proceedings of the National Academy of Sciences 106: 17667–17670.

Clements T, John A, Nielsen K, An D, Tan S, Milner-Gulland EJ. 2010. Payments for biodiversity conservation in the context of weak institutions: Comparison of three programs from Cambodia. Ecological Economics 69: 1283–1291.

Coleman EA, Steed BC. 2009. Monitoring and sanctioning in the commons: An application to forestry. Ecological Economics 68: 2106–2113.

Danielsen F, et al. 2010a. Taking stock of nature in species-rich but economically poor areas: An emerging discipline of locally based monitoring. Pages 88–112 in Lawrence A, ed. Taking Stock of Nature: Participatory Biodiversity Assessment for Policy, Planning, and Practice. Cambridge University Press.

Danielsen F, Burgess ND, Jensen PM, Pirhofer-Walzl K. 2010b. Environmental monitoring: The scale and speed of implementation varies according to the degree of peoples involvement. Journal of Applied Ecology 47: 1166–1168.

Danielsen F, et al. 2011. At the heart of REDD+: A role for local people in monitoring forests? Conservation Letters 4: 158–167.

Dickinson JL, Zuckerberg B, Bonter DN. 2010. Citizen science as an ecological research tool: Challenges and benefits. Annual Review of Ecology, Evolution, and Systematics 41: 149–172.

Fisher B, Kulindwa K, Mwanyoka I, Turner RK, Burgess ND. 2010. Common pool resource management and PES: Lessons and constraints for water PES in Tanzania. Ecological Economics 69: 1253–1261.

Gale GA, Round PD, Pierce AJ, Nimnuan S, Pattanavibool A, Brockelman WY. 2009. A field test of distance sampling methods for a tropical forest bird community. The Auk 126: 439–448.

Gardner TA, et al. 2008. The cost-effectiveness of biodiversity surveys in tropical forests. Ecology Letters 11: 139–150.

Gavin MC, Anderson GJ. 2005. Testing a rapid quantitative ethnobiological technique: First steps towards developing a critical conservation tool. Economic Botany 59: 112–121.

Halme KJ, Bodmer RE. 2007. Correspondence between scientific and traditional ecological knowledge: Rain forest classification by the non-indigenous ribereños in Peruvian Amazonia. Biodiversity and Conservation 16: 1785–1801.

Hellier A, Newton AC, Gaona SO. 1999. Use of indigenous knowledge for rapidly assessing trends in biodiversity: A case study from Chiapas, Mexico. Biodiversity and Conservation 8: 869–889.

Holck MH. 2008. Participatory forest monitoring: An assessment of the accuracy of simple cost-effective methods. Biodiversity and Conservation 17: 2023–2036.

Jack BK, Kousky C, Sims KRE. 2008. Designing payments for ecosystem services: Lessons from previous experience with incentive-based mechanisms. Proceedings of the National Academy of Sciences 105: 9465–9470.

Jones JPG, Andriamarovolona MM, Hockley N, Gibbons JM, Milner-Gulland EJ. 2008. Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. Journal of Applied Ecology 45: 1205–1212.

Léopold M, Cakacaka A, Meo S, Sikolia J, Lecchini D. 2009. Evaluation of the effectiveness of three underwater reef fish monitoring methods in Fiji. Biodiversity and Conservation 18: 3367–3382.

Lunn KE, Dearden P. 2006. Monitoring small-scale marine fisheries: An example from Thailand's Ko Chang archipelago. Fisheries Research 77: 60–71.

Luzar JB, Silvius KM, Overman H, Giery ST, Read JM, Fragoso JMV. 2011. Large-scale environmental monitoring by indigenous people. BioScience 61: 771–781.

Mueller JG, Assanou IHB, Guimbo ID, Almedom AM. 2010. Evaluating rapid participatory rural appraisal as an assessment of ethnoecological knowledge and local biodiversity patterns. Conservation Biology 24: 140–150.

Nagendra H, Ostrom E. 2011. The challenge of forest diagnostics. Ecology and Society 16 (art. 20). (7 November 2013; *www.ecologyandsociety.org/vol16/iss2/art20*)

Nielsen MR, Lund JF. 2012. Seeing white elephants? The production and communication of information in a locally-based monitoring system in Tanzania. Conservation and Society 10: 1–14. (7 November 2013; *www.conservationandsociety.org/text.asp?2012/10/1/1/92188*)

Noss AJ. 1999. Censusing rainforest game species with communal net hunts. African Journal of Ecology 37: 1–11.

Oldekop JA, Bebbington AJ, Berdel F, Truelove NK, Wiersberg T, Preziosi RF. 2011. Testing the accuracy of non-experts in biodiversity monitoring exercises using fern species richness in the Ecuadorian Amazon. Biodiversity and Conservation 20: 2615–2626.

Ostrom E. 2009. A general framework for analyzing sustainability of social-ecological systems. Science 325: 419–422.

Ostrom E, Nagendra H. 2006. Insights on linking forests, trees, and people from the air, on the ground, and in the laboratory. Proceedings of the National Academy of Sciences 103: 19224–19231.

Penrose D, Call SM. 1995. Volunteer monitoring of benthic macroinvertebrates: Regulatory biologists' perspectives. Journal of the North American Benthological Society 14: 203–209.

Peres CA. 1999. General guidelines for standardizing line-transect surveys of tropical forest primates. Neotropical Primates 7: 11–16.

Plumptre AJ. 2000. Monitoring mammal populations with line transect techniques in African forests. Journal of Applied Ecology 37: 356–368.

Rist J, Milner-Gulland EJ, Cowlishaw G, Rowcliffe M. 2010. Hunter reporting of catch per unit effort as a monitoring tool in a bushmeat-harvesting system. Conservation Biology 24: 489–499.

Rist L, Shaanker RU, Milner-Gulland EJ, Ghazoul J. 2010. The use of traditional ecological knowledge in forest management: An example from India. Ecology and Society 15 (art. 3). (7 November 2013; *www.ecologyandsociety.org/vol15/iss1/art3*)

Root TL, Alpert P. 1994. Volunteers and the NBS. Science 263: 1205.

Sodhi NS, Ehrlich PR, eds. 2010. Conservation Biology for All. Oxford University Press.

[UNEP] United Nations Environment Programme. 2012. Report of the Second Session of the Plenary Meeting to Determine Modalities and Institutional Arrangements for an Intergovernmental Science-Policy Interface on Biodiversity and Ecosystem Services. Report no. UNEP/IPBES.MI/2/9. UNEP. (4 February 2014; *http://ipbes.net/resources/previous-ipbes-meetings/second-session-of-plenary.html*)

[UNFCCC] United Nations Framework Convention on Climate Change. 2012. Report of the Conference of the Parties on its Seventeenth Session, Held in Durban from 28 November to 11 December 2011. UNFCCC. Report no. FCCC/CP/2011/9. (7 November 2013; *http://unfccc.int/resource/docs/2011/cop17/eng/09.pdf*)

Uychiaoco AJ, Arceo HO, Green SJ, de la Cruz MT, Gaite PA, Aliño PM. 2005. Monitoring and evaluation of reef protected areas by local fishers in the Philippines: Tightening the adaptive management cycle. Biodiversity and Conservation 14: 2775–2794.

Yasué M, Kaufman L, Vincent ACJ. 2010. Assessing ecological changes in and around marine reserves using community perceptions and biological surveys. Aquatic Conservation: Marine and Freshwater Ecosystems 20: 407–418.

Yoccoz NG, Nichols JD, Boulinier T. 2001. Monitoring of biological diversity in space and time. Trends in Ecology and Evolution 16: 446–453.

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ERRATUM: In Table 7a and 8a, the base for calculation of standard deviation (SD) was the number of observations per minute, while the remaining figures were based on per hour values. This was not mentioned in the Table text. For use in context with mean values, SD can be multiplied with 60 to inform on the variation over the mean. The SD values based on hourly observations are available in the supplemental data set S1.

APPENDIX XV

Danielsen, F., Jensen, P.M., Burgess, N.D., Coronado, I., Holt, S., Poulsen, M.K., Rueda, R.M., Skielboe, T., Enghoff, M., Hemmingsen, L.H., Sørensen, M. and Pirhofer-Walzl, K. 2014.
Testing focus groups as a tool for connecting indigenous and local knowledge on abundance of natural resources with science-based land management systems.
Conservation Letters 7: 380–389.

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LETTER

Testing Focus Groups as a Tool for Connecting Indigenous and Local Knowledge on Abundance of Natural resources with Science-Based Land Management Systems

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Keywords
Community-based natural resource management; cross-cultural management; indigenous and local knowledge systems; knowledge integration; Intergovernmental Platform on Biodiversity and Ecosystem Services; multiple evidence base.

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Received
11 September 2013
Accepted
21 March 2014

Editor
Derek Armitage

doi: 10.1111/conl.12100

Abstract

One of the clearly stated intentions of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) is to bring both "western scientific" and "indigenous and local" knowledge systems within synthetic global, regional, and thematic assessments. A major challenge will be how to use, and quality-assure, information derived from different knowledge systems. We test how indigenous and local knowledge on natural resources in Miskito and Mayangna communities in Nicaragua, validated through focus groups with community members, compares with information collected on line transects by trained scientists. Both provide comparable data on natural resource abundance, but focus groups are eight times cheaper. Such approaches could increase the amount and geographical scope of information available for assessments at all levels, while simultaneously empowering indigenous and local communities who generally have limited engagement in such processes.

Introduction

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) was established in 2012 by 94 Governments, and by January 2014 had 116 Government Members. One of its functions is to produce assessments of the state of the planet's environment, while "recogniz(ing) and respect(ing) the contribution of indigenous and local knowledge" so as "to bring (the) different knowledge systems, including indigenous knowledge systems, into the science-policy interface" (UNEP 2012a). This intention will entail the articulation of indigenous and local knowledge (UNEP 2011; 2012b; Turnhout *et al.* 2012).

A key challenge for IPBES will therefore be how to use information generated by different knowledge systems (Huntington 1998; Colfer *et al.* 2005) within synthetic assessments at the science-policy interface (Sutherland *et al.* 2014). While scientific knowledge is validated primarily through peer-review, other knowledge systems have different validation approaches (Tengö *et al.* 2014). Validation of information *within* knowledge

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systems is well-established, whereas validation *across* knowledge system is a major challenge (Tengö *et al.* 2014). Unidirectional scientific validation of other knowledge systems may compromise the integrity and complexity of the knowledge (Bohensky & Maru 2011; Gratani *et al.* 2011) and promotes power inequality between technocrats and communities (Nadasdy 1999; Bohensky *et al.* 2013). Alternatively, validation of community-based knowledge through a respectful process of collaboration between scientists and community members facilitates mutual learning and empowerment (Cullen-Unsworth *et al.* 2012).

About 370 million indigenous people live on earth—from the tropics to the poles, and include some of the world's poorest and most marginalized communities (United Nations 2009). To participate in decision-making, indigenous people need to translate a well-founded knowledge base on their territories (Dallman *et al.* 2011; UNEP 2013) into a format where it can be heard (Ens *et al.* 2012).

Here, we test a simple approach to document and validate indigenous and local knowledge from Nicaragua using focus group discussions, in comparison with scientific knowledge gathered from line transects.

Methods

Our study was undertaken in the Bosawás Biosphere Reserve in Nicaragua, inhabited by Miskito and Mayangna communities, who use forest as their principal resource base (Koster 2007; Stocks *et al.* 2007). The area is a global priority for conservation (Miller *et al.* 2001). Conventional scientific knowledge is constrained by difficult access, rugged terrain, and frequent heavy rains.

Conceptual framing

We recognize that indigenous knowledge like scientific knowledge implies a way of viewing the world. It is context-specific, hence may lose meaning when applied in other contexts (Stephenson & Moller 2009). In comparison, knowledge on resource abundance, bound by place and time, does not lose its meaning and is relevant to decisions about natural resource management. Berkes (2012) used "local knowledge" when referring to recent knowledge and "indigenous knowledge" for the local knowledge of indigenous peoples, or local knowledge unique to a culture or society. Here, we use the term "indigenous and local knowledge" to emphasize that knowledge of resource abundance is closely linked with knowledge of the resource management systems and the social institutions the management systems operate within (the "knowledge-practice-belief complex;" Berkes 2012).

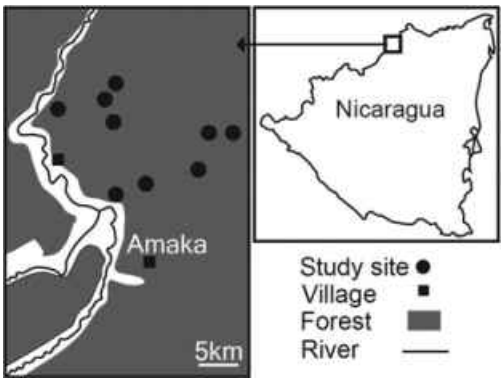

Figure 1 Study area. The location of the nine study sites in the Bosawás Biosphere Reserve, Nicaragua.

While no decision has yet been taken, it seems likely that IPBES will aim to use a multiple (previously called "dual") evidence-based peer-review process (UNEP 2011; Feit *et al.* 2013), where different knowledge systems are viewed as "generating equally valid evidence for interpreting change" (Tengö *et al.* 2014). Many approaches exist to facilitate exchange among knowledge systems (Lynam *et al.* 2007; Raymond *et al.* 2010; Gamborg *et al.* 2012; Padmanaba *et al.* 2013). Central is that "knowledge itself is power" and those who share knowledge should not lose power in the process (Nadasdy 1999).

Our hypothesis is that indigenous and local knowledge on natural resource abundance is valid and can be used in assessment processes, including by IPBES. We test this hypothesis using community-level focus group discussions compared against scientist-executed and community-executed line-transects. Our nine study sites are located opportunistically, 2–15 km from San Andrés and Inipuwás villages, within Bosawás Biosphere Reserve, Nicaragua (Figure 1). Vegetation of all study sites is dense evergreen tropical forest at 50–650 m a.s.l., with various levels of utilization. The area is inhabited by indigenous Miskito and Mayangna who practice subsistence agriculture and harvest nontimber forest products (Appendix S1).

Survey design

Focus groups of community members were established in the same month and year (2007) as line transect routes. Transects were surveyed for animals and plants by community members and trained scientists.

Community members involved in focus groups and line transects lived in the same (indigenous) community and had profound experience of hunting and collecting forest products. When they observe animal tracks, they can identify both the species and the number of

individuals. All community members could count and some were literate. All scientists had degrees in natural science and more than 10 years field experience.

Field methods

Prior to transect fieldwork and focus group discussions, scientists and community members agreed on 10 resources important to the communities for food or other uses (Table 1).

Focus groups

Focus groups are not commonly used by biologists (Sodhi & Ehrlich 2010), but are a standard social science methodology (Table 2; Appendix S2) and a form of group interview that capitalizes on communication between participants to generate data (Kitzinger 1995). For our study, communities were contacted through a civil society organization with long experience working with these communities. We met the General Assembly of Miskitas in the two villages to obtain their advice and approval. Community members volunteered for the focus groups, based on the villagers' interest and experience with forest resources. During participatory planning workshops, members of the focus groups were involved in planning the work and deciding on the use of the results. Focus group members included forest product harvesters, hunters, loggers, local park rangers, and both genders. In each village, we established a volunteer group of 10–20 persons, who observed forest resources at study sites between discussions. From April 2007 to September 2009, these persons took part in 2–3 hour meetings every 3 months. The meetings were facilitated by a group of nonindigenous park rangers. We selected the facilitators based on their skills at communicating equitably among knowledge systems in meetings, and there was no detectable political interplay between the facilitators and community members. The facilitators discussed with communities the abundance of each resource at every study sites in each 3-month period. The following abundance categories were used:

(1) "Many individuals": ≥10 individuals of the resource were recorded in 4 hours of morning walks in the forest.
(2) "Some individuals": 1–9 individuals of the resource were recorded in 4 hours of morning walks in the forest.
(3) "Few individuals": More than 4 hours of morning walks in the forest are required to record one individual of the resource, but the resource is still recorded regularly (≥four times during the 3-month period).
(4) "Very few individuals (or none)": Resource only recorded a few times (<four times) during the 3-month period.

During focus group discussions, the four natural resource abundance categories were broadly interpreted as "many daily," "daily," "less than daily," and "rarely." Abundance estimates provided by the community members were discussed in the local Miskito language. Focus groups' validation was a careful process involving time, commitment, and underlying trust. Community members were in control of the process—agreeing what was right and wrong. Community members involved with line transect surveys were not present during the focus group discussions.

Line transects

This is a commonly used scientific method (Peres 1999; Luzar *et al.* 2011). One scientist recorded sightings and signs of wildlife and plants over 2 hours along a predetermined 2 km transect through the forest, once every 3 months. Village leaders helped select community members, based on their interest and experience with hunting and collecting forest products, to complete line transects along the same routes as the scientists, but on different days. Both scientists and community members kept the speed of walking constant at around 1 km/hour (250 m/15 min, by pacing). The starting time was 06.00–06.30 hours.

Survey costs

We estimated the cost of focus groups, community members, and scientist-executed line transects as the actual expenses incurred during the training and field work at each site (Appendices S3–S4).

Analysis

We compared the abundance assigned by the focus groups for each species at each study site over each 3-month period with abundance from the scientists' and community members' transects. Data are provided in Appendix S5.

First, we compared abundance estimates from scientists' transects with community transects, using *t*-tests of the $\log_e$-transformed densities (counts per hour of survey) (under the LSMEANS statement associated with PROC GLM; SAS 9.1; SAS Institute, Cary, NC, USA). Tests were run both for the classes of organisms individually (mammals, birds, flora) and in combination in a full generalized linear model (PROC GLM). Independent variables were (classes of organisms): birds, mammals, or

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Table 1 Comparison between number of individuals of mammals, birds, and plants observed by community members and scientists during 43 community members' and 43 trained scientists' 2-hour transect walks in nine study sites between 2007 and 2009 in the Bosawás Biosphere Reserve, Nicaragua

			Number of individuals observed	
Class	Latin name	English/local name	Community member transect walks	Trained scientists transect walks
Mammalia	*Odocoileus virginianus*	White-tailed deer/Venado cola blanca	7	5
	Mazama americana	Red brocket/Cabrito	11	8
	Agouti paca	Paca/Guardiola, tepezcuintle	18	8
	Dasypus novemcinctus	Nine-banded armadillo/Cusuco	21	18
Aves	*Ara ambigua*	Buffon's macaw/Lapa verde	18	21
	Crax rubra	Great curassow/Pavón	36	29
	Ramphastos sulfuratus, *R. swainsonii*, and *Pteroglossus torquatus*	Keel-billed toucan/Tucán pico iris, Chestnut-mandibled toucan/Tucán de swainson, and Collared aracari/Tucancillo	378	312
Flora	*Trichilia quadrijuga* ssp. *cinerascens*	Cacao[a]	646	381
	Protium glabrum and Tetragastris panamensis	Kerosín[a]	740	471
	Castilla tunu	Tuno[a]	1,474	1,348

[a]No English name.

plants; and (observers): scientist or community member. Since scientist and community transects produced largely similar results, we used the mean densities obtained from these two sets of results for comparison with the reports from the focus groups discussions in the villages adjacent to the transect routes.

Second, we compared mean abundance estimates from trained scientists' transects and community transects with abundance categories derived from focus groups, using paired *t*-tests for each class of organism and in combination in a partial generalized linear model, with classes and focus group abundance categories as independent variables (but no interaction). We used Tukey correction for pairwise comparison of densities within classes, under the LSMEANS statement. The correlation between scientists' transects, community member transects, and focus group reports was evaluated using PROC CORR SPEARMAN.

Third, we discussed the preliminary results with the communities. We returned the findings to them so that they could see for themselves how their observations connected with results from other methods, and could be used to promote indigenous and local inputs into reserve management. This two-way process was essential. It helped underline that the study was not information "harvesting" but a collaborative undertaking.

Results

Comparing scientists' and community members' transect results

Our test of different methods of generating knowledge was based on 430 tripled records from focus groups, scientists, and community member transects for the same 10 resources (three plants, three birds, and four mammal taxa), in the same areas (nine sites, Figure 1), and at the same time (3-month period). We first tested differences in the recorded relative abundance of resources between scientists and community member transects. No significant differences were recorded between estimated abundance of mammals ($P = 0.28$; df = 438, $t = -1.07$), birds ($P = 0.58$; df = 328; $t = -0.54$), or plants ($P = 0.08$; df = 88; $t = -1.76$), made by scientists and community members along the same transect routes. We repeated the test using a full generalized model that explained most of the variation in the data ($R^2 = 0.79$; $P < 0.001$). Again, we found that the relative abundance of resources recorded by community member transect surveys match those recorded by scientist transects over a range of forest resources, although there is a tendency ($P < 0.1$) for scientists' transects to count fewer individuals than community member transects (Tables 1 and 3). Likewise, we found a strong positive correlation between the estimates of mammal, bird, and plant abundance emanating from community member and scientist transects ($r_s = 0.78$; $P < 0.001$; $n = 430$).

Comparing transect results with abundance estimates from focus groups

Comparing focus groups and averaged transect results, we found that focus group discussions were unable to differentiate between what community members and scientists considered "very few," "few," and "some individuals," but that resources reported as plentiful ("many

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Table 2 Examples of attributes previously assessed with the use of focus groups for collecting data

Discipline	Attribute(s) studied	Study*
Life science	Changes in the composition of plant species grown in home gardens	Sunwar *et al.* 2006; Abay *et al.* 2008
	Contribution of wetland resources to household food security	Turyahabwe *et al.* 2013
	Ethnobotanical knowledge	Ndoro *et al.* 2007; Odugbemi *et al.* 2007; Luziatelli *et al.* 2010; Termote *et al.* 2010; Mekonnen & Lemma 2011; Muthee *et al.* 2011; Grasser *et al.* 2012; Derbile 2013; Hasan *et al.* 2013
	Ethnozoological knowledge	Lohani 2010, 2011; Devi *et al.* 2013
	Ethnopharmacological knowledge	Uprety *et al.* 2010; Maliwichi-Nyirenda *et al.* 2011; Namukobe *et al.* 2011; Mncwangi *et al.* 2012; Muthee *et al.* 2011
	Evaluation of participatory land-use planning in communities	Kaswamila & Songorwa 2009; Yonas *et al.* 2013
	Farmer's views and experiences in shrimp culture activities	Paul & Vogl 2013
	Impacts of fuelwood collection on deforestation	Nagothu 2001
	Local abundance and use of 25 wildlife species	Loucks *et al.* 2009
	Local perceptions of the status of woody species and of the threats to their conservation	Tabuti *et al.* 2009
	Local practices in water quality monitoring and water management	Nare *et al.* 2006; Nhapi 2009
	Poverty and livelihood impacts of a medicinal and aromatic plants project	Rasul *et al.* 2012
	Problems in forest and landscape management operations that could be resolved by the use of remote sensing	Takao *et al.* 2010
	Selection of agrienvironmental indicators	Belanger *et al.* 2012
	The use of nontimber forest products to support local livelihoods	Camou-Guerrero 2008; Challe & Struik 2008; Varghese & Ticktin 2008; Giliba *et al.* 2010; Terer *et al.* 2012
Health and social sciences	Consumption of indigenous forest foods	Msuya *et al.* 2010
	Commonly consumed food and recipes	Ene-Obong *et al.* 2013
	Evaluation of learning methods in communities	Zahidah *et al.* 2011
	Farmers' perspectives on growing perennial "energy'' grasses	Cope *et al.* 2011
	Impacts of biofuel industry on local communities	Selfa *et al.* 2011
	Indigenous communities impression of new established conservation sites	Nkemnyi *et al.* 2013
	Mode of governing natural resources	Ngwenya *et al.* 2012; Bown *et al.* 2013
	People's experiences of disease	Ejobi *et al.* 2007; Legesse *et al.* 2011

*See Appendix S2 for literature cited.

individuals") were significantly different from all other categories for all types of resources (Figure 2; statistics in Table 4). Similar results were obtained when repeating the test using a linear model, which combined all records, adjusted for differences in densities between classes, and explained most of the variation ($R^2 = 0.85$, $P < 0.001$).

The apparent inability of focus group reports to differentiate between the three categories of least abundance was caused by high standard deviation within focus group category 4 ("very few") and fairly even densities of focus group category 3 ("few individuals") and 2 ("some individuals") (see Figure 2). Reducing the number of abundance categories from four to three, by merging "few individuals" and "some individuals," delivered a clearer separation of densities for birds and plants, although not for mammals. Likewise, we found that Spearman correlation coefficients for transect densities and focus group categories were 0.43 ($P < 0.001$), 0.06 ($P = 0.32$), and 0.30 ($P = 0.04$) for birds, mammals, and plants, respectively, suggesting a stepwise reduction in densities against focus group categories for birds and plants, but not for mammals.

Comparing costs of transect surveys and focus groups

Across all nine study sites, measurements through focus group discussions cost significantly less than

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Table 3 Results of focus groups' statements of abundance, based on the number of sites and 3-month periods where each statement was provided, and the average abundance indices (number of individuals observed per hour, with SE) from community members' (C) and trained scientists' (S) transect walks of 10 resources recorded between 2007 and 2009 at nine study sites in the Bosawás Biosphere Reserve, Nicaragua

	Counts of focus groups' statements of abundance per index for each type of organisms				Mean abundance indices for community transects (C) and scientists transects (S) (number of individuals observed per hour)			
Focus group abundance index	*Aves* *n* (%)	*Flora* *n* (%)	*Mammalia* *n* (%)	Total *n*		*Aves*	*Flora*	*Mammalia*
"Very few individuals''	13	0	54	67	C	0.46 ± 0.26	0.0	0.06 ± 0.02
	(7%)	(0%)	(24%)		S	0.03 ± 0.03	0.0	0.06 ± 0.02
"Few individuals"	59	14	72	145	C	0.81 ± 0.15	27.5 ± 4.9	0.10 ± 0.03
	(35%)	(31%)	(32%)		S	0.77 ± 0.15	14.5 ± 1.8	0.07 ± 0.03
"Some individuals"	63	25	89	177	C	1.09 ± 0.17	27.6 ± 4.0	0.07 ± 0.02
	(38%)	(55%)	(40%)		S	1.12 ± 0.17	23.7 ± 3.8	0.04 ± 0.01
"Many individuals"	30	6	5	41	C	2.71 ± 0.43	59.4 ± 14.2	0.70 ± 0.25
	(18%)	(13%)	(2%)		S	2.38 ± 0.37	50.9 ± 13.6	0.80 ± 0.40
Total	165	45	220	430				
	(100%)	(100%)	(100%)					

Table 4 Results of paired *t*-tests comparing focus groups' statements of abundance and the average abundance indices (number of individuals observed per hour, with SE) from community members' and trained scientists' transect walks of 10 bird, plant, and mammal resources recorded between 2007 and 2009 at nine study sites in the Bosawás Biosphere Reserve, Nicaragua

Class	Focus group abundance index	Transects, mean no. of individuals observed per hour*	SE	*t*-test†
Aves	"Very few individuals"	0.25	0.37	a,b
$n = 165$	"Few individuals"	0.80	0.17	a,b,c
	"Some individuals"	1.11	0.17	b,c
	"Many individuals"	2.55	0.24	d
Flora	"Very few individuals"	0.0	N.A	N.A.
$n = 45$	"Few individuals"	20.96	5.19	a,b
	"Some individuals"	25.62	3.88	a,b
	"Many individuals"	55.17	7.92	c
Mammalia	"Very few individuals"	0.06	0.03	a,b,c
$n = 220$	"Few individuals"	0.09	0.02	a,b,c
	"Some individuals"	0.06	0.02	a,b,c
	"Many individuals"	0.75	0.09	d

N.A. = not applicable.

*Average abundance indices of community members' and trained scientists' transect walks.

†Means with the same letter are not significantly different ($P < 0.05$).

community members and scientists transects ($P < 0.001$; $n = 9$; Figure 3, Appendices S3–S4). Likewise, community transects were significantly cheaper than scientists transects ($P < 0.001$; $n = 9$).

Discussion

Our results suggest that over a range of life-forms of birds, mammals, and plants, indigenous and local knowledge documented and validated with focus groups provides similar abundance indices of wild species as trained scientists and community members transects. The strongest agreement between focus groups and transects was for birds and plants, with lower agreement for mammals. This might be because mammals were mainly recorded by foot prints and dung along transects, while birds and plants were directly observed; hence, the number of mammals recorded on transects is subject to substantial individual interpretation.

Our findings suggest that for participants in focus groups, the meaning of individual abundance indices varies between taxa. For instance, mammals recorded

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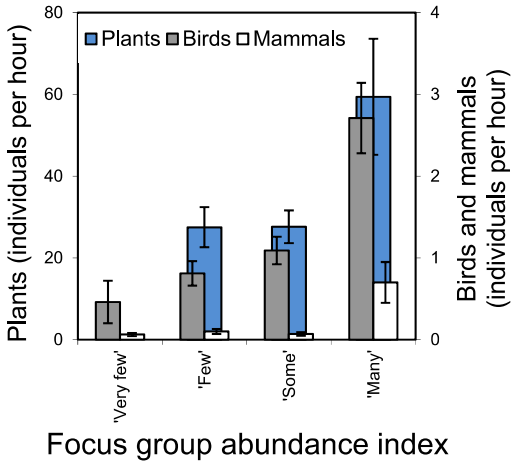

Figure 2 Relationship between focus groups' statements of abundance of 10 plant, bird, and mammal forest resources and the average abundance indices (number of individuals observed per hour, with SE) of the same resources obtained by community members' and trained scientists' transect walks between 2007 and 2009 at nine study sites in the Bosawás Biosphere Reserve, Nicaragua. The figure is based on 430 tripled records from focus groups, scientists', and community members' transects for the same resources, in the same areas, and at the same time (3-month period).

in both scientists' and community members' transects at 0.7–0.8 individuals per hour are considered "many individuals' by the focus groups, whereas birds recorded on transects with the same density are considered to be "few individuals" in the same focus groups (Table 3). Focus groups are thus not reporting relative encounter frequency, but are "automatically" integrating community expectations, i.e., recording something as less abundant when fewer than expected are recorded given its identity (perhaps) size, or interest as food.

In the scientific knowledge system, reliability has two components, conformity to fact (lack of bias) and precision (exactness). Our findings suggest that villagers' focus group assessments of abundance are of similar accuracy (unbiased) to scientists' and community members' transects. We did not examine the precision of the focus groups' assessments, because abundance values from the focus groups are categorical, which hampers assessment of precision.

How representative and broadly applicable are our findings? We know of only one previous study of focus group results with direct counts of natural resources (Mueller *et al.* 2010). This compared assessments of species richness, diversity, and height of grasses and trees by community members from a village in Niger, with direct counts made by scientists. The study found a good match on height and density for grasses and trees and tree species richness, but it found poor correlation on herb species richness and Simpson's *D* value for both trees and grasses. The study does, however, suffer from different temporal scale and different times for community members' focus group discussions and direct counts, thus preventing conclusions on the reliability of the focus group (Danielsen *et al.* 2014).

Are focus groups more or less reliable than individual interviews? It seems certain that some information is lost when data are not written but only memorized (Jones *et al.* 2008). Moreover, focus groups, like other methods, are only as reliable as the participants, and governance structures can always encourage or discourage reliable provision of information (Nielsen & Lund 2012).

In our study area, the community members have good knowledge of the forest (Koster 2007), and the resources studied were of interest to the communities and they knew them well. In our opinion, community members had no incentive to mislead by deliberately providing erroneous information.

Focus groups involve interaction between group members (Gibbs 1997). Although the views of the most powerful members of the group might bias the results of focus groups, our observations were that when potentially inaccurate information was provided by one or a few participants, after discussion, this information was generally corrected. Hence, the conclusion represented the group consensus.

The "process" aspect of the focus groups was perceived to be very important by the community members. Focus group discussions were undertaken in an open learning process, where the community focus group members participated directly with the right to vote and express opinions. They were themselves the "gate keepers" detecting and deciding which data were complete and which were false, or out of context, and therefore should be discarded. Our findings suggest that community members' ownership of the data and information and their control over the knowledge, the validation process, and the application of the knowledge were critical to their sense of empowerment (Stephenson & Moller 2009; Huntington 2011).

In conclusion, our findings suggest that using focus groups for validating indigenous and local knowledge on natural resources could increase the information available for measuring status and trends in natural resources, while at the same time contributing to empower indigenous and local communities. Guidelines describe how to promote the use of indigenous knowledge (Tkarihwaié:ri Code; Convention on Biological Diversity 2011). To aid this process and increase the ability of community focus groups to provide natural resource abundance data which scientists would consider reliable, we propose a series of recommendations (Table 5). The approach should, however, not be rolled out uncritically—representatives of indigenous and local communities should decide whether focus groups on resource abundance can help enable

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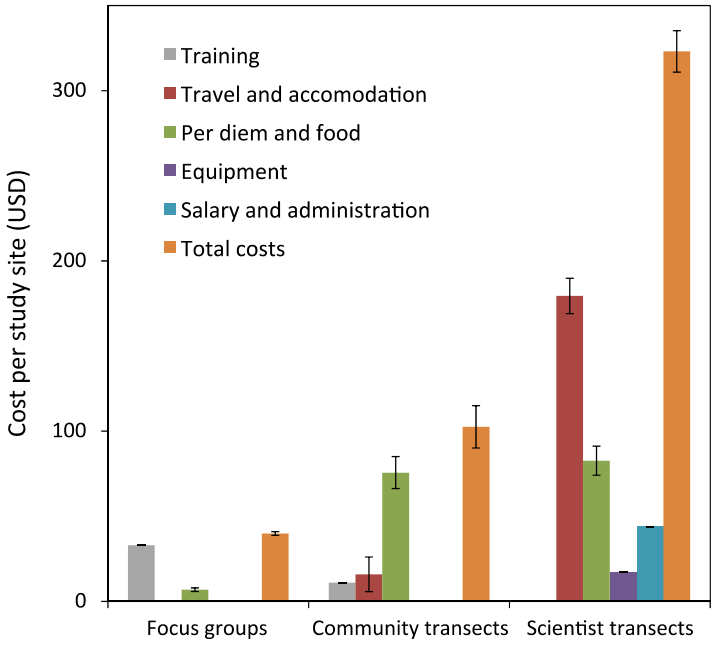

Figure 3 Costs of focus groups, community members' transects, and trained scientists' transects per study site in each 3-month study period (in USD 2013; with SD).

Table 5 Recommendations for how to increase the ability of community focus groups to provide natural resource abundance data which scientists would consider reliable

1. Establish independent focus groups in multiple communities that know resource abundance in the same geographical area (triangulation across communities)
2. Convene regularly, e.g., annually, village meetings to present and discuss data and interpretation and obtain feedback from the entire community (triangulation across community members)
3. Facilitate the collection of auxiliary data through, e.g., community members' direct counts of resources in the same area (triangulation across methods)
4. Include individuals within the focus groups who are themselves directly involved with using and observing natural resources (thereby increasing the number of primary data providers)
5. Use unequivocal categories for resource abundance
6. Ensure that the moderator of the focus group discussions has skills and experience in facilitating dialogues

them be heard. The UN Declaration on the Rights of Indigenous Peoples states that development must take place in accordance with their "Free, Prior and Informed Consent" (United Nations 2008). Focus groups may also represent a useful starting point from which broader regional and national monitoring and assessment programs, tailored to the local conditions, could be designed and implemented.

Promoting approaches such as this could be an important element of the work of IPBES as it seeks to fulfill its mandate to recognize and respect the contribution of indigenous and local knowledge. While IPBES is widely recognized as an assessment process, and needs to draw on information from multiple sources, it also has three other functions: promoting generation of knowledge; delivery of policy support tools and methodologies; and capacity building. IPBES therefore has a potentially strong role to play in promoting the use of new approaches that allow the improved capture of data and information, in promoting means for bringing together data and information from different knowledge systems, and in building capacity to do both. This is therefore an important area of work to develop more formally within the framework of IPBES assessments, not only to feed the IPBES assessments themselves, but so that such approaches are used at all levels.

Acknowledgments

We thank M. Funder, N.J. Johnson, J.P.G. Jones, P. Malmer, M. Schultz, V. Tauli-Corpuz, and M. Tengö for inspiring discussions and J. Harrison and S. Hvalkof for insightful guidance. This work was funded by the Danish Council for Development Research.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Appendix S1. Study area.
Appendix S2. References used for Table 2.

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Appendix S3. Details of how the costs of plant, mammal, and bird data from focus group discussions, community members', and trained scientists' transect walks were calculated.

Appendix S4. Cost of focus group discussions, community members' transects and trained scientists' transects (in USD per study site and per 3-month period).

Appendix S5. Data collected in the Bosawás Bioshere Reserve in Nicaragua over the period April 2007 to September 2009.

References

Berkes, F. (2012). *Sacred ecology*, 3rd ed., Routledge, New York.

Bohensky, E.L., Butler, J.R.A. & Davies, J. (2013). Integrating indigenous ecological knowledge and science in natural resource management: perspectives from Australia. *Ecol. Soc.*, **18**, 20.

Bohensky, E.L. & Maru, Y. (2011). Indigenous knowledge, science, and resilience: what have we learned from a decade of international literature on "integration"? *Ecol. Soc.*, **16**, 6.

Colfer, C.J.P., Colchester, M., Joshi, L., Puri, R.K., Nygren, A. & Lopez, C. (2005). Traditional knowledge and human well-being in the 21st century. Pages 173-182 in G. Mery, R. Alfaro, M. Kanninen, M. Lobovikov, editors. *Forests in the global balance—changing paradigms*, Vol. **17**, IUFRO World Series. International Union of Forest Research Organizations, Helsinki, Finland.

Convention on Biological Diversity. (2011). *Tkarihwaié:ri - code of ethical conduct to ensure respect for the cultural and intellectual heritage of indigenous and local communities relevant to the conservation and sustainable use of biological diversity*. Secretariat of the Convention on Biological Diversity, Montreal, Canada. http://www.cbd.int/traditional/code/ethicalconduct-brochure-en.pdf (visited January 15, 2014).

Cullen-Unsworth, L.C., Hill, R., Butler, J.R.A. & Wallace, M. (2012). A research process for integrating Indigenous and scientific knowledge in cultural landscapes: principles and determinants of success in the Wet Tropics World Heritage Area, Australia. *Geogr. J.*, **178**, 351-365.

Dallman, W.K., Peskov, V., Murashko, O.A. & Khmeleva, E. (2011). Reindeer herders in the Timan-Pechora oil province of Northwest Russia: an assessment of interacting environmental, social, and legal challenges. *Pol. Geogr.*, **34**, 229-247.

Danielsen, F., Jensen, P.M., Burgess, N.D., *et al.* (2014). A multicountry assessment of tropical resource monitoring by local communities. *BioScience*, **64**, 236-251.

Ens, E.J., Finlayson, M., Preuss, K., Jackson, S. & Holcombe, S. (2012). Australian approaches for managing 'country' using Indigenous and non-Indigenous knowledge. *Ecol. Manage. Restor.*, **13**, 100-107.

Feit, U., Korn, H. & Paulsch, A., editors. (2013). *Report of the International Expert Workshop connecting diverse Knowledge Systems in the context of IPBES. BfN-Skripten 341*. Bundesamt für Naturschutz, Bonn, Germany.

Gamborg, C., Parsons, R., Puri, R.K. & Sandøe, P. (2012). Ethics and research methodologies for the study of traditional forest-related knowledge. Pages 535-560 in J.A. Parrotta, R.L. Trosper, editors. *Traditional forest-related knowledge: sustaining communities, ecosystems and biocultural diversity*, World Forests, Vol. **12**., Springer, Netherlands.

Gibbs, A. (1997). Focus groups. *Social Res. Update*, **19**. http://sru.soc.surrey.ac.uk/SRU19.html (visited January 15, 2014).

Gratani, M., Butler, J.R.A., Royee, F., *et al.* (2011). Is validation of Indigenous ecological knowledge a disrespectful process? A case study of traditional fishing poisons and invasive fish management from the Wet Tropics, Australia. *Ecol. Soc.*, **16**(3), 25.

Huntington, H.P. (1998). Observations on the utility of the semi-directive interview for documenting traditional ecological knowledge. *Arctic*, **51**, 237-242.

Huntington, H.P. (2011). The local perspective. *Nature*, **478**, 182-183.

Jones, J.P., Andriamarovololona, M.M., Hockley, N., Gibbons, J.M. & Milner-Gulland, E.J. (2008). Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. *J. Appl. Ecol.*, **45**, 1205-1212.

Kitzinger, J. (1995). Qualitative research-introducing focus groups. *Br. Med. J.*, **311**, 299-302.

Koster, J.M. (2007). Hunting and subsistence among the Mayangna and Miskito of Nicaragua's Bosawas Biosphere Reserve. Doctoral dissertation, The Pennsylvania State University.

Luzar, J.B., Silvius, K.M., Overman, H., Giery, S.T., Read, J.M. & Fragoso, J.M.V. (2011). Large-scale environmental monitoring by indigenous people. *BioScience*, **61**, 771-781.

Lynam, T., de Jong, W., Sheil, D., Kusumanto, T. & Evans, K. (2007). A review of tools for incorporating community knowledge, preferences, and values into decision-making in natural resources management. *Ecol. Soc.*, **12**, 5.

Miller, K., Chang, E. & Johnson, N. (2001). *Defining common ground for the Mesoamerican Biological Corridor*. World Resources Institute, Washington, DC.

Mueller, J.G., Assanou, I.H.B., Guimbo, I.D. & Almedom, A.M. (2010). Evaluating rapid participatory rural appraisal as an assessment of ethnoecological knowledge and local biodiversity patterns. *Conserv. Biol.*, **24**, 140-150.

Nadasdy, P. (1999). The politics of TEK: power and the "integration" of knowledge. *Arctic Anthropol.*, **36**, 1-18.

Nielsen M.R. & Lund, J.F. (2012). Seeing white elephants? The production and communication of information in a locally-based monitoring system in Tanzania. *Conserv. Soc.*, **10**, 1-14. http://www.conservationandsociety.org/text.asp?2012/10/1/1/92188 (visited January 15, 2014).

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Padmanaba, M., Sheil, D., Basuki, I. & Liswanti, N. (2013). Accessing local knowledge to identify where species of conservation concern occur in a tropical forest landscape. *Environ. Manage.* **52**(2), 348-359.

Peres, C.A. (1999). General guidelines for standardizing line-transect surveys of tropical forest primates. *Neotrop. Prim.*, **7**, 11-16.

Raymond, C.M., Fazey, I., Reed, M.S., Stringer, L.C., Robinson, G.M. & Evely, A.C. (2010). Integrating local and scientific knowledge for environmental management. *J. Environ. Manage.*, **91**, 1766-1777.

Sodhi, N.S. & Ehrlich, P.R., editors. (2010). *Conservation biology for all*. Oxford University Press, New York.

Stephenson, J. & Moller, H. (2009). Cross-cultural environmental research and management: challenges and progress. *J. R. Soc. New Zealand*, **39**, 139-149.

Stocks, A., McMahan, B. & Taber, P. (2007). Indigenous, colonist, and government impacts on Nicaragua's Bosawas Reserve. *Conserv. Biol.*, **21**, 1495-1505.

Sutherland, W.J., Gardner, T.A, Haider, L.J. & Dicks, L.V. (2014). How can local and traditional knowledge be effectively incorporated into international assessments? *Oryx,* **48**, 1-2.

Tengö, M., Brondizio, E., Elmqvist, T., Malmer, P. & Spierenburg, M. (2014). Connecting diverse knowledge systems for enhanced ecosystem governance – the multiple evidence base approach. *Ambio*, DOI 10.1007/s13280-014-0501-3.

Turnhout, E., Bloomfield, B., Hulme, M., Vogel, J. & Wynne, B. (2012). Listen to the voices of experience. *Nature*, **488**, 454-455.

United Nations. (2008). *Declaration on the Rights of Indigenous Peoples*. United Nations. http://www.un.org/esa/socdev/unpfii/documents/DRIPS_en.pdf (visited January 15, 2014).

United Nations. (2009). *State of the World's Indigenous Peoples. United Nations Department of Economic and Social Affairs, Division for Social Policy and Development, Secretariat of the Permanent Forum on Indigenous Issues ST/ESA/328*. www.un.org/esa/socdev/unpfii/documents/SOWIP_web.pdf (visited January 15, 2014).

UNEP (United Nations Environment Programme). (2011). *Report of an international science workshop on assessments for an intergovernmental science-policy platform on biodiversity and ecosystem services, held in Tokyo from 25 to 29 July 2011*. UNEP/IPBES.MI/1/INF/12. http://ipbes.net/resources/previous-ipbes-meetings/first-session-of-plenary.html (visited February 4, 2014).

UNEP (United Nations Environment Programme). (2012a). *Report of the second session of the plenary meeting to determine modalities and institutional arrangements for an intergovernmental science-policy interface on biodiversity and ecosystem services*. UNEP/IPBES.MI/2/9. http://ipbes.net/resources/previous-ipbes-meetings/second-session-of-plenary.html (visited February 4, 2014)

UNEP (United Nations Environment Programme). (2012b). *Consideration of initial elements: recognizing indigenous and local knowledge and building synergies with science*. IPBES/1/INF/5. http://www.ipbes.net/plenary/ipbes-1.html (visited February 4, 2014).

UNEP (United Nations Environment Programme). (2013). *Indicators relevant for traditional knowledge and customary sustainable use. UNEP/CBD/WG8J/8/9*. https://www.cbd.int/doc/?meeting=WG8J-08 (visited January 15, 2014).

APPENDIX XVI

Danielsen, F., Burgess, N. and Topp-Jørgensen, E. 2007.
Native Knowledge.
Science www.sciencemag.org/cgi/eletters/315/5818/1518.

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NATIVE KNOWLEDGE

J. Couzin's article "Opening Doors to Native Knowledge" (News, 16 March, p. 1518) revealed the trend toward increased collaboration between scientific and local cultures in providing answers to climate-change questions in the Arctic. We believe that polar science could benefit from experiences from those developing countries where a suite of locally based approaches to environmental assessment are emerging (1).

Two factors make these techniques particularly relevant in the Arctic. First, locally based methods appear effective in incorporating evidence-based assessments in decision-making at the local level (2), and, by their nature, locally based methods tend to focus on issues of greatest concern to local stakeholders, thus having considerable potential to influence on-the-ground management activities. Second, locally based methods can track the delivery of goods and services from natural ecosystems, which are a prime focus of several international environmental agreements (3), yet are extremely hard to monitor using a top-down approach (1). Without proper monitoring of ecosystem benefits, the success of these international agreements cannot be evaluated, exposing them to criticism or abandonment.

Locally based approaches are, however, vulnerable to various sources of bias. Problems include a risk, in the absence of careful documentation, of methods drifting over time or of results reflecting long-term perceptions more than current trends. This caveat is also relevant in the Arctic. We propose that thorough comparison of data collected by local stakeholders and scientists is an important avenue for further research.

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References

1. See www.monitoringmatters.org/cases.htm

2. F. Danielsen et al., Ambio 36, 566-570.

3. Report on the 6th Meeting of the Conference of the Parties to the Convention on Biological Diversity, Strategic Plan Decision VI/26 (UNEP, Nairobi, Kenya, 2002).

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APPENDIX XVII

Huntington, H.P., **Danielsen, F.**, Enghoff, M., Levermann, N., Løvstrøm, P., Schiøtz, M., Svoboda, M. and Topp-Jørgensen, E. 2013. Conservation through community involvement. Pg. 644–647 in: *Arctic Biodiversity Assessment. Status and trends in Arctic biodiversity* (Ed. H. Meltofte). Conservation of Arctic Flora and Fauna, Akureyi, Iceland.

19.4.3. Conservation through community involvement

The last several decades have seen continued interest in natural resource monitoring that involves both scientists and local stakeholders (Gofman 2010, Huntington 2011). This partnership, often referred to as community based monitoring (CBM), or community-based observations, continues to evolve and exert increased influence on decision making and resource management (Gofman 2010). The scope of CBM is diverse and complex and continues to develop as experiences of integration are shared. Moreover, the overwhelming connection of Arctic peoples to the land provides opportunities for strong conservation partnerships, for example initiatives related to ecological monitoring, food security or sacred sites.

In essence, CBM seeks to improve the ability to share observations and understanding of local changes that are occurring in a vast and remote region through the eyes of Arctic residents. The idea is that intimate and multi-generational knowledge held by local stakeholders can help governments and local organizations identify and address serious environment and development challenges at early stages (Harremoës *et al.* 2001).

19.4.3.1. Monitoring approaches

Monitoring approaches in all Arctic countries have some level of local involvement, and examples of CBM exist throughout the Arctic. These monitoring approaches range from programs involving local stakeholders only in data collection (citizen science) with the design, analysis and interpretation undertaken by professional researchers, to entirely autonomous monitoring schemes run by local people (see Gofman 2010 for full discussion).

The level of involvement by local peoples beyond project development and planning to include analysis can contribute to longer-term capacity and implementation benefits beyond just the collected data (Tab. 19.3). Although local residents can unquestionably monitor and report on certain observed changes, their interpretation of the changes and any policy implications they may have are sometimes left aside. However, this is not a problem limited to CBM. From a policy implementation perspective, opportunities to involve Arctic peoples in knowledge production, in an open and transparent manner, is critical when considering managing individual and commercial activities in the North.

19.4.3.2. Validity of CBM data

The struggle to break through the perceived limitations surrounding CBM is often linked to the approaches and skepticism at the heart of western approaches to knowledge production. Scientists have documented Arctic community members' detailed knowledge of key components of their environment, such as sea-ice (Laid-

Table 19.3. Arctic and sub-Arctic natural resource monitoring schemes across a spectrum of possible monitoring approaches based on the relative participation of different actors (modified from Danielsen *et al.* 2009).

Category of monitoring	Arctic examples	Description
Fully autonomous local monitoring	Customary conservation regimes, e.g. in Canada (Ferguson *et al*. 1998, Moller *et al.* 2004)	The whole monitoring process – from design, to data collection, to analysis, and finally to use of data for management decisions – is carried out autonomously by local stakeholders
Collaborative monitoring with local data interpretation	Arctic Borderlands Ecological Knowledge Co-op, Canada (Eamer 2006, Russell *et al.* 2013); Community-based monitoring by Inuvialuit Settlement region, Canada (Huntington 2011); Opening Doors to the Native Knowledge of the Indigenous Peoples of the Nenet Autonomous Okrug, Russia (The Association of the Nenets People Yasavey and RAIPON); Piniakkanik Sumiiffinni Nalunaarsuineq, Greenland (Danielsen *et al.* in press)	Locally based monitoring involving local stakeholders in data collection, interpretation or analysis, and management decision making, although external scientists may provide advice and training. The original data collected by local people remain in the area being monitored, but copies of the data may be sent to professional researchers for in-depth or larger-scale analysis
Collaborative monitoring with external data interpretation	Community Moose Monitoring Project, Canada (Gofman 2010); Integrated Ecosystem Management (ECORA), Russia (Larsen *et al.* 2011)	Local stakeholders involved in data collection and monitoring-based management decision making, but the design of the scheme and the data analysis and interpretation are undertaken by external scientists
Externally driven monitoring with local data collectors	Bering Sea Sub Network, Alaska and Russia (Gofman & Smith 2009); Environmental Observations of Seal Hunters, Finland (Gofman 2010); Fávllis Network, Norway (Gofman 2010); Monitoring of breeding common eiders, Greenland (Merkel 2010); The Piniarneq fisheries catch and hunting report database, Greenland	Local stakeholders involved only in data collection stage, with design, analysis and interpretation of monitoring results for decision-making being undertaken by professional researchers, generally far from the site
Externally driven, researcher executed monitoring	Multiple scientist-executed natural resource monitoring schemes with no involvement of the local stakeholders	Design and implementation conducted entirely by professional scientists who are funded by external agencies and generally reside elsewhere

ler 2006), weather patterns (Weatherhead *et al.* 2010) and caribou (Ferguson *et al.* 1998, Russell *et al*. 2013). Nevertheless, we know of no studies that have examined the accuracy of community-based monitoring of natural resources in the Arctic. Studies from other parts of the world provide cautious support for the idea that monitoring by community members can yield results that can be as reliable as those derived from professional, scientist-conducted monitoring (e.g. Danielsen *et al.* 2005, Jones *et al.* 2008, Rist *et al.* 2010).

Whereas scientists aspire to be impartial (Beardsley 2010), some fishermen, hunters and environmentally interested people may have a conflict of interest in their assessment of the status of those resources on which they depend for their livelihoods or that they are otherwise interested in (Root & Alpert 1994). For instance, a special local interest in certain resources or a preoccupation with certain challenges to resource management may influence which attributes are recorded, when and where. The community perspective is relevant too. Indigenous communities often view scientific initiatives with suspicion, if the scientists do not possess social and cultural skills to appreciate context and locality, creating a need to establish credibility in both directions.

Many of the potential limitations of CBM can be overcome by careful planning, by explicit consideration of likely biases, and by thorough training and supervision of the participants (Danielsen *et al.* 2009, Gofman 2010, Luzar *et al.* 2011). It is a challenge, however, that community monitoring can superficially appear low-tech and therefore primitive in a high-tech world. There remains a huge unexplored potential for strengthening monitoring efforts across the Arctic by engaging more communities and encouraging linkages with scientific monitoring programs (Huntington 2008). Often, an investment to build capacity to collect, interpret and manage data are central to maximizing such monitoring efforts (Gofman 2010).

19.4.3.3. Challenges

As the CBM record evolves and demonstrates continued improvement of accessible information on Arctic biodiversity, it is anticipated that there will be a delay between information production and use, accessibility and integration. In northwestern Canada and northeastern Alaska, for example, the reporting by the Arctic Borderlands Ecological Knowledge Co-op of CBM data on population health and body condition of the Porcupine caribou herd were largely dismissed and undervalued in favor of scientific models projecting substantive

population declines (Gofman 2010, Russell *et al.* 2013). Moreover, such projected declines prompted government and decision makers to push for and build harvest regimes that limited northern residents' ability to harvest. Indeed in 2012, several years after the CBM results were released, scientific population surveys revealed record numbers of caribou actually existed. In this case, CBM would have limited harvest concerns and supported improved access to northern food. However, the combination of the potential for conflict of interest and the lack of demonstrable validation capacity may have contributed to placing limited value on the information from this source.

Such examples suggest that efforts to emphasize analysis and integration between the two knowledge production approaches should continue. Indeed, more recent biodiversity monitoring planning processes are proposing ways of integrating and coordinating the methods for knowledge co-production (Gofman 2010, Vongraven *et al.* 2012). The Circumpolar Biodiversity Monitoring Program's (CBMP) strategy for bridging some of the structural challenges over the next few years includes improving the access to CBM data via improved provision of and access to metadata, modeling and demonstrating integration examples of CBM with scientific monitoring processes (Gill *et al.* 2011, Culp *et al.* 2012).

19.4.3.4. Contributions to biodiversity monitoring

Full participation in biodiversity monitoring programs continues to be a challenge for many Arctic peoples. Greenland's effort to increase involvement of CBM with management provides one of the promissong stories becoming more common in the Arctic. The Greenland government is piloting a natural resource monitoring system whereby local people and local authority staff are directly involved in data collection, interpretation and resource management. The scheme is called *Piniakkanik sumiiffinni nalunaarsuineq* (Opening Doors to Native Knowledge). Four communities in Disko Bay and Umanak/Uummannaq Fjord are involved: Akunnaaq, Kitsissuarsuit, Qaarsut and Jakobshavn/Ilulissat.

As in other parts of the Arctic, the communities in Greenland are widely distributed over a vast territory, and the opportunities for environmental monitoring and for implementing hunting and fishing regulations on the ground are limited. It has long been a priority of the Greenland government to increase the involvement of local citizens in the decision-making process related to natural resources (Greenland Government 1999, Haaland *et al.* 2005). However, there is limited funding available for monitoring Greenland's resources, and many species and populations are thus monitored infrequently or not at all (Nielsen 2009). There is therefore insufficient knowledge available about some wildlife populations to guide government decision making and consequently a need to supplement the existing scientist-led monitoring programs with low-cost monitoring, for example through CBM.

The following are examples of how the influence and impact of the data are increasing when it comes to Arctic resource management. In each of the examples, local community observations were central to effecting changes to management regimes.

Conservation of marine habitat: In Akunnaaq, Greenland, the Natural Resource Committee (NRC) recorded trawlers fishing for shrimp in a shallow sea area adjacent to their village on a daily basis. There were 4-5 vessels almost every day throughout April and May 2010. This number was the same as in 2009 but higher than in previous years. Moreover, the vessels were larger and used heavier fishing gear. The NRC in Akunnaaq was worried that potential degradation of the seafloor might affect the breeding and production of Atlantic wolf-fish *Anarhichas lupus*. The NRC therefore proposed that the municipality should issue an ordinance to restrict the size of vessels in the area.

Influencing marine harvest techniques: One of the attributes recorded by Qaarsut NRC concerned their catch of Greenland halibut *Reinhardtius hippoglossoides* in Umanak/Uummannaq Fjord. On the basis of their catch-and-effort data from long-line fishery, they estimated that the local Greenland halibut population was the same in May 2010 but higher in June-September 2010 than in the same months of 2009. Nevertheless, the NRC was concerned that many nets were being set over their longlines and that some nets were left at sea when the sea froze over. This resulted in many rotting fish, which attracted Greenland sharks *Somniosus microcephalus*. The NRC therefore proposed that the municipality should issue an ordinance to restrict net fishing in Umanak/Uummannaq Fjord. The fisheries legislation in Greenland allows municipalities – subject to ministerial approval – to prohibit the use of certain vessels and equipment in specific areas (Greenland Government 1996).

Influencing goose harvest pressure: Members of the Qaarsut NRC have observed that, over the past decade, the population of Canada goose *Branta canadensis* has risen sharply. Canada goose may out-compete the threatened Greenland white-fronted goose *Anser albifrons flavirostris* (Boyd & Fox 2008 *versus* Raundrup *et al.* 2012). Hunting seasons in Greenland are decided by the Ministry of Fisheries, Hunting and Agriculture on the basis of advice from scientists and from public input during a hearing process. The current hunting season for Canada goose is 15 August to 15 October (Department of Fisheries, Hunting and Agriculture 2011). The NRC proposed that the municipality should suggest to the Ministry that the hunting season for Canada goose be extended, for example by two weeks, to help keep the population from expanding further. However, a recent study has not found such competition between Canada geese and Greenland white-fronts during molt (Raundrup *et al.* 2012).

In all three examples, it is noteworthy that the proposals if implemented will benefit the people having put them forward. International experiences however suggest that

CBM also often leads to people suggesting restrictions in their own take of resources (Danielsen *et al.* 2007). CBM encourages people to take a long term perspective on the use of resources through facilitating agreements at community and municipal level to increase or reduce the use of resources.

19.4.3.5. Future prospects

The Arctic environment is rapidly changing (e.g. Hinzman *et al.* 2005, CAFF 2010) and there is increasing pressure on its natural resources. There is therefore also an increased need for monitoring. To date, many examples exist of Arctic peoples describing the changes they witness related to climate, sea ice and especially to harvested wildlife species. There is a persistent need for more CBM that can detect change, interpret and integrate results, and lead to prompt decision-making to help tackle environmental challenges at operational levels of resource management (Huntington & Fox 2005, Danielsen *et al.* 2010).

Representatives of indigenous communities practice wildlife management guided by their indigenous knowledge, realizing that indigenous knowledge and western scientific knowledge are based on different knowledge generation systems or epistemologies (e.g. Agrawal 1995, Huntington *et al.* 2004). Through CBM, however, it may be possible to find a suitable means of cooperation and collaboration in which monitoring can be based on local observations and knowledge (Pulsifer *et al.* 2010, van der Velden 2010) and, at the same time, follow principles of data handling and data management in accordance with Western concepts of scientific accuracy (Yoccoz *et al.* 2001), which is what national government agencies and international conventions require. Several Arctic programs (including the CBMP) and Arctic peoples have already started to implement strategies to bridge this gap by building structures such as inventories and metadatabases to better access, use and integrate CBM knowledge in the arctic (e.g. Pulsifer *et al.* 2012).

In combination, the increased need for data and the necessity of promoting locally relevant knowledge and management actions suggest that there are substantial prospects in the coming decades for more CBM around the Arctic, and that such an increase will contribute to effective local conservation actions.

REFERENCES

Agrawal, A. 1995. Dismantling the divide between indigenous and scientific knowledge. Dev. Change 26: 413-439.

AMAP 1998. Arctic Pollution Issues: a State of the Arctic Environment Report. Arctic Monitoring and Assessment Programme, Oslo.

AMAP 2007. Arctic Oil and Gas 2007. Arctic Monitoring and Assessment Program, Oslo.

AMSA 2009. Arctic Marine Shipping Assessment 2009 Report. Protection of the Arctic Marine Environment, Ottawa, Canada.

Barry, T. & McLennan, D. 2010. Changes in protected areas. In: CAFF. Arctic Biodiversity Trends 2010 – Selected Indicators of Change, pp 96-98. CAFF International Secretariat, Akureyri.

Beardsley, T.M. 2010. Emotions and engagement. BioScience 60: 775.

Bellamy, D., Radforth, J. & Radforth, N.W. 1971. Terrain, traffic and tundra. Nature 231: 429-432.

Betts, R.A. 2000. Offset of the potential carbon sink from boreal forestation by decreases in surface albedo. Nature 408: 187-190.

Bliss, L.C. 1970a. A biologist explains why we must plan now to protect the Arctic. Science Forum 3(8): 3-8.

Bliss, L.C. 1970b. Oil and the ecology of the Arctic. In: The tundra environment. Transactions of the Royal Society of Canada, Series IV, 7: 1-12.

Boyd, H. & Fox, A.D. 2008. Effects of climate change on the breeding success of White-fronted Geese *Anser albifrons flavirostris* in west Greenland. Wildfowl 58: 55-70.

CAFF 2004. The conservation value of sacred sites of indigenous peoples of the Arctic: a case study in Northern Russia. Report on the state of sacred sites and sanctuaries. CAFF Technical Report No. 11. CAFF International Secretariat, Akureyri.

CAFF 2010. Arctic Biodiversity Trends 2010 – selected indicators of change. CAFF International Secretariat, Akureyri.

Callaghan, T.V., Björn, L.O., Chapin III, F.S., Chernov, Y., Christensen, T.R., Huntley, B. *et al*. 2005. Arctic tundra and polar desert ecosystems. In: ACIA. Arctic Climate Impact Assessment, pp 243-352. Cambridge University Press, Cambridge.

Cameron, R.D., Smith, W.T., White, R.G. & Griffith, B. 2005. Central Arctic caribou and petroleum development: distributional, nutritional and reproductive implications. Arctic 58: 1-10.

Canadell, J.G. & Raupach, M.R. 2009. Land carbon cycle feedbacks. In: M. Sommerkorn & S.J. Hassol (eds.). Arctic Climate Feedbacks: Global Implications, pp 69-80. WWF International Arctic Programme, Oslo.

CARMA 2010. Threats to Caribou. www.carmanetwork.com/display/public/Threats [accessed 12 December 2010]

Chapin, F.S. III, Sturm, M., Serreze, M.C., McFadden, J.P., Key, J.R., Lloyd, A.H. *et al*. 2005. Role of land-surface changes in arctic summer warming. Science 310: 657-660.

Chapin, F.S. III, Carpenter, S.R., Kofinas, G.P., Folke, C., Abel, N., Clark, W.C. *et al*. 2009a. Ecosystem stewardship: sustainability strategies for a rapidly changing planet. Trends in Ecology and Evolution 24: 241-249.

Chapin, F.S. III, Kofinas, G.P. & Folke, C. (eds.) 2009b. Principles of Ecosystem Stewardship Springer, New York.

Christie, P. & Sommerkorn, M. 2012. RaCeR: Rapid assessment of circum-arctic ecosystem resilience, 2nd ed. WWF Global Arctic Programme, Ottawa.

Crawford, R.M.M. (ed.) 1997. Disturbance and Recovery in Arctic Lands: An Ecological Perspective. Kluwer Academic, Dordrecht.

Culp, J.M., Lento, J., Goedkoop, W., Power, M., Rautio, M., Christoffersen, K.S. et al. 2012. Developing a circumpolar monitoring framework for Arctic freshwater biodiversity. Biodiversity 13: 215-227.

Danielsen, F., Burgess, N.D. & Balmford, A. 2005. Monitoring matters: examining the potential of locally-based approaches. Biodiv. Conserv. 14: 2507-2542.

Danielsen, F., Mendoza, M.M., Tagtag, A., Alviola, P.A., Balete, D.S., Jensen, A.E. *et al*. 2007. Increasing conservation management action by involving local people in natural resource monitoring. Ambio 36: 566-570.

Danielsen, F., Burgess, N.D., Balmford, A., Donald, P.F., Funder, M., Jones, J.P.G. *et al*. 2009. Local participation in natural resource monitoring: a characterization of approaches. Conserv. Biol. 23: 31–42.

Danielsen, F., Burgess, N.D., Jensen, P.M. & Pirhofer-Walzl, K. 2010. Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples involvement. J. Appl. Ecol. 47: 1166-1168.

Danielsen, F., Topp-Jørgensen, E., Levermann, N., Løvstrøm, P., Schiøtz, M., Enghoff, M. *et al*. in press. Counting what counts: using local knowledge to improve Arctic resource management. Polar Geography.

Department of Fisheries, Hunting and Agriculture 2011. dk.nanoq.gl/Emner/Erhverv/Erhvervsomraader/Fangst_og_Jagt/Jagttider.aspx [accessed 20 January 2012]

DFO 2008. Canada/Greenland Joint Commission on Narwhal and Belugas. www.dfo-mpo.gc.ca/CSAS/Csas/Publications/SAR-AS/2008/SAR-AS2008_035_E.pdf [accessed 14 June 2011]

Dowsley, M. 2010. The value of a polar bear: evaluating the role of a multiple-use resource in the Nunavut mixed economy. Arctic Anthropology 47: 39-56.

Dudley, N. (ed.) 2008. Guidelines for Applying Protected Area Management Categories. IUCN, Gland.

Eamer, J. 2006. Keep it simple and be relevant: the first nine years of the Arctic Borderlands Ecological Knowledge Co-op. In: W.V. Reid, F. Berkes, T. Wilbanks & D. Capistrano (eds.). Bridging Scales and Knowledge Systems, pp 185-206. Island Press, Washington DC.

Euskirchen, E.S., McGuire, A.D. & Chapin, F.S. III 2007. Energy feedbacks of northern high-latitude ecosystems to the climate system due to reduced snow cover during 20th century warming. Global Change Biology 13: 2425-2438

Euskirchen, E.S., McGuire, A.D., Chapin, F.S. III, Yi, S. & Thompson, C.C. 2009. Changes in plant communities in northern Alaska under scenarios of climate change 2003-2100:

Implications for climate feedbacks. *Ecological Applications* **19**: 1022-1043.
Euskirchen, E.S., McGuire, A.D., Chapin, F.S. III & Rupp, T.S. 2010. The changing effects of Alaska boreal forests on the climate system. Canadian Journal of Forest Research 40: 1336-1346.
Ferguson, M.A.D., Williamson, R.G. & Messier, F. 1998. Inuit Knowledge of Long-term Changes in a Population of Arctic Tundra Caribou. Arctic 51: 201-219.
Forbes, B.C. 1995. Tundra disturbance studies. III. Short-term effects of aeolian sand and dust, Yamal Region, northwest Siberia, Russia. Environmental Conservation 22: 335-344.
Forbes, B.C. 1997. Tundra disturbance studies. IV. Species establishment on anthropogenic primary surfaces, Yamal Peninsula, Northwest Siberia, Russia. Polar Geography 21: 79-100.
Forbes, B.C. & Kumpula, T. 2009. The ecological role and geography of reindeer (Rangifer tarandus) in northern Eurasia. Geography Compass 3/4: 1356-1380.
Forbes, B.C. & McKendrick, J.D. 2002. Polar tundra. In: M. Perrow & A.J. Davy (eds.). Handbook of Ecological Restoration, Vol. 2: Restoration in Practice, pp 355-375. Cambridge University Press, Cambridge.
Forbes, B.C., Ebersole, J.J. & Strandberg, B. 2001. Anthropogenic disturbance and patch dynamics in circumpolar arctic ecosystems. Conservation Biology 15: 954-969.
Forbes, B.C., Stammler, F., Kumpula, T., Meschtyb, N., Pajunen, A. & Kaarlejärvi, E. 2009. High resilience in the Yamal-Nenets social-ecological system, West Siberian Arctic, Russia. Proceedings of the National Academy of Sciences 106: 22041-22048.
Forbes, B.C., Macias-Fauria, M. & Zetterberg, P. 2010. Russian Arctic warming and 'greening' are closely tracked by tundra shrub willows. Global Change Biology 16: 1542-1554.
Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W. *et al*. 2007. Changes in Atmospheric Constituents and in Radiative Forcing. IPCC Fourth Assessment Report WG1. Cambridge University Press, Cambridge.
Gilders, M.A. & Cronin, M.A. 2000. North Slope oil field development. In: J.C. Truett & S.R. Johnson (eds.). The Natural History of an Arctic Oil Field – Development and the Biota, pp 15-33. Academic Press, San Diego.
Gill, M., Crane, K., Hindrum, R., Arneberg, P., Bysveen, I., Denisenko, N.V. *et al*. 2011. Arctic Marine Biodiversity Monitoring Plan (CBMP-MARINE PLAN), CAFF Monitoring Series Report No. 3, April 2011, CAFF International Secretariat, Akureyri, Iceland.
Gofman, V. 2010. Community based monitoring handbook: lessons from the Arctic. CAFF CBMP Report No. 21. CAFF, Akureyri.
Gofman, V. & Smith, M. 2009. Bering Sub-Sea Network Pilot Phase Final Report. CAFF Monitoring Series Report No. 2. CAFF, Akureyri.
Goldenberg, S. 2011. BP's Gulf of Mexico oil spill was 'caused by cost-cutting'. The Guardian Weekly 14 January 2011, p 17.
Graham, B. & Reilly, W.K. 2011. Deepwater: The Gulf Oil Disaster and the Future of Offshore Drilling. Report to the President. National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, Washington.
Greenland Government 1996. Landstingslov nr. 18 af 31. oktober 1996 om fiskeri. www.lovgivning.gl/gh.gl-love/dk/1996/Ltl/ltl_nr_18-1996_dk.htm [accessed 20 January 2012]
Greenland Government 1999. Landstingslov nr. 12 af 29. oktober 1999 om fangst og jagt, §2 stk. 3. dk.nanoq.gl [accessed 20 February 2012]
Haaland, H., Skogen, K., Landa, A., Loeks, D., Andersen, O., Aastrup, P. *et al*. 2005. Uddelegering af forvaltningsansvar – levende ressourcer i Grønland. NINA Rapport 6.
Harremoës, P., Gee, D., MacGarvin, M., Stirling, A., Keys, J., Wynne, B. *et al*. (eds.) 2001. Late Lessons from Early Warnings: The Precautionary Principle 1896-2000. Environmental Issue Report 22. European Environment Agency, Copenhagen.
Haskell, S.P., Nielson, R.M., Ballard, W.B., Cronin, M.A. & McDonald, T.L. 2006. Dynamic responses of calving caribou to oilfields in northern Alaska. Arctic 59: 179-190.
Heiskanen, J., Nilsson, B., Mäki, A-H., Allard, A., Moen, J., Holm, S. *et al*. 2008. Aerial photo interpretation for change detection of treeline ecotones in the Swedish mountains. www.resgeom.slu.se/resana/NILS/Publikationer/arb_rapp_242.pdf [accessed 15 June 2011]
Helldin, J.O., Jung, J., Neumann, W., Olsson, M., Skarin, A. & Widemo, F. 2012. The impacts of wind power on terrestrial mammals: a synthesis. Report 6510. Swedish Environmental Protection Agency, Stockholm.
Henry, G. & Elmendorf, S. 2010. Greening of the Arctic. In: CAFF. Arctic Biodiversity Trends 2010: Selected Indicators of Change, pp 62-64. CAFF International Secretariat, Akureyri.
Hinzman, L.D., Bettez, N.D., Bolton, W.R., Chapin, F.S., Dyurgerov, M.B., Fastie, C.L. *et al*. 2005. Evidence and implications of recent climate change in Northern Alaska and other Arctic regions. Clim. Change 72: 251-298.
Hu, F.S., Higuera, P.E., Walsh, J.E., Chapman, W.L., Duffy, P.A., Brubaker, L.B. & Chipman, M.L. 2010. Tundra burning in Alaska: Linkages to climatic changes and sea ice retreat. Journal of Geophysical Research 115: 1-8.
Hummel, M. & Ray, J. 2008. Caribou and the North: A Shared Future. Dundurn Press, Toronto.
Huntington, H. 2008. A Strategy for Facilitating and Promoting Community-Based Monitoring Approaches in Arctic Biodiversity Monitoring. CAFF CBMP Report No. 13.
Huntington, H.P. 2011. Arctic science – the local perspective. Nature 478: 182-183.
Huntington, H. & Fox, S. 2005. The changing Arctic: indigenous perspectives. In: ACIA. Arctic Climate Impact Assessment, pp 61-98. Cambridge University Press, Cambridge.
Huntington, H., Callaghan, T., Fox, S. & Krupnik, I. 2004. Matching traditional and scientific observations to detect environmental change: A discussion on Arctic terrestrial ecosystems. Ambio 13: 18-23.
Jernelöv, A. 2010. How to defend against future oil spills. Nature 466: 182-183.
John, E. & Turkington, R. 1997. A 5-year study of the effects of nutrient availability and herbivory on two boreal forest herbs. Journal of Ecology 85: 419-430.
Jokinen, M. (ed.) 2005. Poronhoidon ja suojelun vaikutukset Mallan luonnonpuistossa. Metsäntutkimuslaitoksen tiedonantoja [Finnish Forest Research Institute Research Papers] 941.
Jones, J.P.G., Andriamarovolona, M.M., Hockley, N.J., Gibbons, J.M. & Milner-Gulland, E.J. 2008. Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. J. Appl. Ecol. 45: 1205-1212.
Jorgenson, M.T., Racine, C.H., Walters, J.C. & Osterkamp, T.E. 2001. Permafrost degradation and ecological changes associated with a warming climate in central Alaska. Climate Change 48: 551-579.
Kevan, P.G., Forbes, B.C., Kevan, S.M. & Behan-Pelletier, V.M. 1995. Vehicle tracks on high Arctic tundra: their effects on the soil, vegetation, and soil arthropods. Journal of Applied Ecology 32: 655-667.
Key, S.L. & Stohl, A. 2007. Arctic air pollution: Origins and impacts. Science 315: 1537-1540.
Khitun, O. 1997. Self-recovery after technogenic and natural disturbances in the central part of the Yamal Peninsula (Western Siberian Arctic). In: R.M.M. Crawford (ed.). Disturbance and Recovery in Arctic Lands: An Ecological Perspective, pp 531-562. Kluwer, Dordrecht.
Khitun, O. & Rebristaya, O. 2002. Anthropogenic impacts on habitat structure and species richness in the West Siberian Arctic. In: A.E. Watson, L. Alessa & J. Sproull (eds.). Wilderness in the Circumpolar North, pp 85-95. USDA-FS, Rocky Mountain Research Station, Ogden.
Kumpula, T., Pajunen, A., Kaarlejärvi, E.M., Forbes, B.C. & Stammler, F. 2011. Land use and land cover change in arctic Russia: ecological and social implications of industrial development. Global Environmental Change 21: 550-562.

Kumpula, T., Forbes, B.C., Stammler, F. & Meschtyb, N. 2012. Dynamics of a coupled system: multi-resolution remote sensing in assessing social-ecological responses during 25 years of gas field development in Arctic Russia. Remote Sens. 4: 1046-1068.

Laidler, G.J. 2006. Inuit and scientific perspectives on the relationship between sea ice and climate change: the ideal complement? Climate Change 78: 407-444.

Larsen T. & Stirling, I. 2009. The Agreement on the Conservation of Polar Bears – its History and Future. Rapportserie Nr. 127, Norsk Polarinstitutt, Tromsø.

Larsen, T.S., Kurvits, T. & Kuznetsov, E. 2011. Lessons learned from ECORA – An integrated ecosystem management approach to conserve biodiversity and minimize habitat fragmentation in the Russian Arctic. CAFF Strategy Series Report No. 4.

Lassuy, D. & Lewis, P.N. 2010. Invasive species (human-induced). In: CAFF. Arctic Biodiversity Trends 2010: Selected Indicators of Change. CAFF International Secretariat, Akureyri.

Lawrence, D.M., Slater, A.G., Tomas, R.A., Holland, M.M. & Deser, C. 2008. Accelerated Arctic land warming and permafrost degradation during rapid sea ice loss. Geophysical Research Letters 35: L11506

Lemieux, C.J. & Scott, D.J. 2005. Climate change, biodiversity conservation and protected area planning in Canada. Canadian Geographer 49: 384-399.

Light, B., Grenfell, T.C. & Perovich, D.K. 2008. Transmission and absorption of solar radiation by Arctic sea ice during the melt season. Journal of Geophysical Research 113: 1-19.

Livingston, D. 2011. Circumpolar Protected Areas Monitoring. Arctic Protected Areas Monitoring Scheme Background Paper. CAFF International Secretariat, CAFF Monitoring Series Report Nr. 5.

Lloyd, A.H., Rupp, T.S., Fastie, C.L. & Starfield, A.M. 2003. Patterns and dynamics of treeline advance on the Seward Peninsula, Alaska. Journal of Geophysical Research 108: 1-15.

Luzar, J.B., Silvius, K.M., Overman, H., Giery, S.T., Read, J.M. & Fragoso, J.M.V. 2011. Large-scale environmental monitoring by indigenous people. BioScience 61: 771-781.

Macias-Fauria, M., Forbes, B.C., Zetterberg, P. & Kumpula, T. 2012. Eurasian Arctic greening reveals teleconnections and the potential for structurally novel ecosystems. Nature Climate Change 2: 613-618.

Margesin, R. & Schinner, F. 1999. Biotechnological Applications of Cold-Adapted Organisms. Springer-Verlag, Heidelberg.

McGuire, A.D., Chapin, F.S. III, Walsh, J.E. & Wirth, C. 2006. Integrated regional changes in Arctic climate feedbacks: Implications for the global climate system. Annual Review of Environmental Resources 31: 61-91.

McGuire, A.D., Anderson, L.G., Christensen, T.R., Dallimore, S., Guo, L., Hayes, D.J. *et al*. 2009. Sensitivity of the carbon cycle in the Arctic to climate change. Ecological Monographs 79: 523-555.

McGuire, A.D., Chapin, F.S. III & Ruess, R.W. (eds.) 2010. Dynamics of change in Alaska's boreal forests: resilience and vulnerability in response to climate warming. Can. J. For. Res. 40(7).

Meek, C.L. 2011. Putting the US polar bear debate into context: the disconnect between old policy and new problems. Journal of Marine Policy 35: 430-439.

Meltofte, H., Piersma, T., Boyd, H., McCaffery, B., Ganter, B., Golovnyuk, V.V. *et al.* 2007: Effects of climate variation on the breeding ecology of Arctic shorebirds. – Meddr. Grønland, Biosci. 59: 1-48.

Merkel, F. 2010. Evidence of recent population recovery in common eiders breeding in Western Greenland. Journal of Wildlife Management 74: 1869-1874.

Meschtyb, N.A. 2008. Aleuts. In: L. Sillanpää (ed.). Awakening Siberia – From Marginalization to Self-Determination: the Small Indigenous Nations of Northern Russia on the Eve of the Millennium. Acta Politica No. 33. Department of Political Science, University of Helsinki, Helsinki.

Moller, H., Berkes, F., Lyver, P.O. & Kislaioglu, M. 2004. Combining science and traditional ecological knowledge: monitoring populations for co-management. Ecology and Society 9(3), article no. 2.

Mustonen, T. 2009. Karhun väen ajast-aikojen avartuva avara. Tutkimus kolmen euraasialaisen luontaistalousyhteisön paikallisesta tiedosta pohjoisen ilmastonmuutoksen kehyksessä. University of Joensuu.

Mustonen, T. 2012. Metsäveri – Aslak Ola Aikion elämää ja tarinoita. Snowchange Cooperative.

Myers-Smith, I.H., Arnesen, B.K., Thompson, R.M. & Chapin, F.S. III. 2006. Cumulative impacts on Alaskan Arctic tundra of a quarter century of road dust. Écoscience 13: 503-510.

Myhre, G. 2009. Consistency between satellite-derived and modeled estimates of the direct aerosol effect. Science 325: 187-190.

National Research Council 2003. Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope. National Academies Press, Washington.

Nellemann, C. Kullerud, L., Vistnes, I., Forbes, B.C., Husby, E., Kofinas, G.P. *et al*. 2001. GLOBIO Global methodology for mapping human impacts on the biosphere: the Arctic 2050 scenario and global application. UNEP/DEWA Technical Report 3. United Nations Environment Programme, Nairobi.

Nielsen, M.R. 2009. Is climate change causing the increasing narwhal (*Monodon monoceros*) catches in Smith Sound, Greenland? Polar Research 28: 238-245.

Novikova, N.I. 2008. Eskimos. In: L. Sillanpää (ed.). Awakening Siberia – From Marginalization to Self-Determination: the Small Indigenous Nations of Northern Russia on the Eve of the Millennium. Acta Politica No. 33. Department of Political Science, University of Helsinki.

NSIDC (National Snow and Ice Data Center) 2010. nsidc.org [accessed 12 January 2010]

NY Times 2011a. Failure in the Gulf. New York Times 7 January 2011: A22.

NY Times 2011b. The verdict on the spill. New York Times 11 January 2011: A22.

Olofsson, J., Oksanen, L., Callaghan, T., Hulme, P.E., Oksanen, T. & Suominen, O. 2009. Herbivores inhibit climate-driven shrub expansion on the tundra. Global Change Biology 15: 2681-2693.

Oozeva, C., Noongwook, C., Noongwook, G., Alowa, C. & Krupnik, I. 2004. Watching ice and weather our way. Arctic Studies Center, Smithsonian Institution, Washington, DC.

Pedersen, C.A., Roeckner, E., Lüthje, M. & Winther, J.-G. 2009. A new sea ice albedo scheme including melt ponds for ECHAM5 general circulation model. J. Geophys. Res. 114, D08101.

Perovich, D., Meier, W., Tschudi, M., Gerland, S. & Richter-Menge, J. 2012. Arctic report card: update for 2012: sea ice. www.arctic.noaa.gov/reportcard/sea_ice.html [accessed 7 December 2012]

Post, E. & Pedersen, C. 2008. Opposing plant community responses to warming with and without herbivores. PNAS 105: 12353-12358.

Pulsifer, P.L., Laidler, G.J., Taylor, D.R.F. & Hayes, A. 2010. Towards an Indigenist data management program: reflections on experiences developing an atlas of sea ice knowledge and use. Can. Geog. 55: 108-124.

Pulsifer, P., Gearheard, S., Huntington, H.P., Parsons, M.A., McNeave, C. & McCann, H.S. 2012. The role of data management in engaging communities in Arctic research: overview of the Exchange for Local Observations and Knowledge of the Arctic (ELOKA). Polar Geography 35: 271-290.

Rasmussen, R.O, & Koroleva, N.E. (eds.) 2003. Social and Environmental Impacts in the North. Kluwer, Dordrecht.

Raundrup, K., Levermann, N. & Poulsen, M. 2012. Overlap in diet and distribution of two goose species suggests potential for competition at a common moulting area in West Greenland. Dansk. Orn. Foren. Tidsskr. 106: 93-100.

Regehr, E.V., Lunn, N.J., Amstrup, S.C. & Stirling, I. 2007. Effects of earlier sea ice breakup on survival and population size of polar bears in Western Hudson Bay Journal of Wildlife Management 71: 2673-2683.

Regehr, E.V., Hunter, C.M., Caswell, H., Amstrup, S.C. & Stirling, I. 2010. Survival and breeding of polar bears in the Southern Beaufort Sea in relation to sea ice. Journal of Animal Ecology 79: 117-127.

Riordan, B., Verbyla, D. & McGuire, A.D. 2006. Shrinking ponds in subarctic Alaska based on 1950-2002 remotely sensed images. J. Geophys. Res. 111: 1-11.

Rist, J., Milner-Gulland, E.J., Cowlishaw, G. & Rowcliffe, M. 2010. Hunter Reporting of Catch Per Unit Effort as a Monitoring Tool in a Bushmeat-Harvesting System. Conserv. Biol. 24: 489-499.

Root, T. & Alpert, P. 1994. Volunteers and the NBS. Science 263: 1205.

Rouse, W.R., Oswald, C.J., Binyamin, J., Spence, C., Schertzer, W.M., Blanken, P.D. *et al*. 2005. The role of northern lakes in a regional energy balance. J. Hydrometeorology 6: 291-305.

Russell, D.E., Svoboda, M., Arokium, J. & Cooley, D. 2013. Arctic Borderlands Ecological Knowledge Cooperative: can local knowledge inform caribou management? Rangifer 33(21): 71-78.

Schuur, E.A.G, Bockheim, J., Canadell, J., Euskirchen, E.S., Field, C., Goryachkin, S. *et al*. 2008. The vulnerability of permafrost carbon to climate change: implications for the global carbon cycle. Bioscience 58: 701-714.

Scott, D.A. 1998. Global Overview of the Conservation of Arctic Migratory Breeding Birds outside the Arctic – 1998. Wetlands International Publication No. 45. CAFF Technical Report No. 4. CAFF, Akureyri.

Shindell, D. & Faluvegi, G. 2009 Climate response to regional radiative forcing during the twentieth century. Nature Geoscience 2: 294-300.

Smith, L.C., Sheng, Y., MacDonald, G.M. & Hinzman, L.D. 2005. Disappearing arctic lakes. Science 308: 1429.

Stammler, F. & Forbes, B.C. 2006. Oil and gas development in the Russian Arctic: West Siberia and Timan-Pechora. IWGIA Newsletter Indigenous Affairs, Arctic Oil and Gas Development 2-3/06: 48-57.

Stroeve, J., Holland, M.M., Meier, W., Scambos, T. & Serreze, M. 2007. Arctic sea ice decline: Faster than forecast. Geophysical Research Letters 34: 1-5.

Sturm, M., Racine, C.R. & Tape, K. 2001. Increasing shrub abundance in the Arctic, Nature 411: 546-547.

Sturm, M., Douglas, T., Racine, C. & Liston, G.E. 2005. Changing snow and shrub conditions affect albedo with global implications. Journal of Geophysical Research 110, G01004.

Tarnocai, C., Canadell, J.C., Schuur, E.A.G., Kuhry, P., Mazhitova, G. & Zimov, S. 2009. Soil organic carbon pools in the northern circumpolar permafrost region. Global Biogeochemical Cycles 23: 1-11.

van der Velden, M. 2010. Design for the contact zone. In: F. Sudweeks, H. Hrachovec & C. Ess (eds.) Proceedings Cultural Attitudes Towards Communications and Technology 2010, pp 1-18. Murdoch University, Australia.

Vistnes, I. & Nellemann, C. 2008. The matter of spatial and temporal scales: a review of reindeer and caribou response to human activity. Polar Biology 31: 399-407.

VNIPIGazdovycha 2005. Baseline for Investments in the Development of Bovanenkovo Deposit on the Yamal Peninsula and Gas Transport, Vols. 3 and 7 (in Russian). VNIPIGazdovycha, Saratov and VNIIGaz, Moscow.

Vongraven, D., Aars, J., Amstrup, S., Atkinson, S., Belikov, S., Born, E. *et al*. 2012. A circumpolar monitoring plan for polar bears. Ursus 23(2):1-66.

Walker, D.A. 1996. Disturbance and recovery of arctic Alaskan vegetation. Ecological Studies 120: 35-71.

Walter, K.M., Smith, L.C. & Chapin, F.S. III. 2007. Methane bubbling from northern lakes: present and future contributions to the global methane budget. Philos. Trans. Royal Society 365: 1657-1676.

Wang, M. & Overland, J. 2009. A sea ice free summer Arctic within 30 years? Geophys. Res. Lett. 36: L07502.

Weatherhead, E., Gearheard, S. & Barry, R.G. 2010. Changes in weather persistence: Insight from Inuit knowledge. Global Environ. Change 20: 523-528.

Wiig, Ø., Aars, J. & Born, E.W. 2008. Effects of climate change on polar bears. ScienceProgress 91: 151-173.

Wild, R. & McLeod, C. (eds.) 2008. Sacred Natural Sites: Guidelines for Protected Area Managers. IUCN, Gland.

Yoccoz, N.G., Nichols, J.D. & Boulinier, T. 2001. Monitoring of biological diversity in space and time. Trends Ecol. Evol. 16: 446-453.

Zhang, T., Frauenfeld, O.W., Serreze, M.C., Etringer, A., Oelke, C., McCreight, J. *et al*. 2005. Spatial and temporal variability in active layer thickness over the Russian Arctic drainage basin. Journal of Geophysical Research 110, D16101.

Zhuang, Q., Melillo, J.M., Sarofim, M.C., Kicklighter, D.W., McGuire, A., Felzer, B.S. *et al*. 2006. CO_2 and CH_4 exchanges between land ecosystems and the atmosphere in northern high latitudes over the 21st century. Geophysical Research Letters 33: L17403.

Zöckler, C., Hla, T.H., Clark, N. & Morozov, V. 2010. Spoon-billed Sandpiper. Recovery Team News Bulletin No 4 (May). www.shorebird-network.net/PDFs/Sbs-news-bulletin-May-2010.pdf [accessed 15 June 2011]

APPENDIX XVIII

Danielsen, F., Mendoza, M.M., Tagtag, A., Alviola, P.A., Balete, D.S., Jensen, A.E., Enghoff, M. and Poulsen, M.K. 2007.
Increasing conservation management action by involving local people in natural resource monitoring.
Ambio 36: 566–570.

Report

Finn Danielsen, Marlynn M. Mendoza, Anson Tagtag, Phillip A. Alviola, Danilo S. Balete, Arne E. Jensen, Martin Enghoff and Michael K. Poulsen

Increasing Conservation Management Action by Involving Local People in Natural Resource Monitoring

There is a need for a better understanding of the status of the environment. At the same time, concerns have been raised regarding alienation of the local populace from environmental decisions. One proposed solution is participatory environmental monitoring. When evaluating the usefulness of environmental monitoring, the focus may be on accuracy, as is usually done by scientists, or on efficiency in terms of conservation impact. To test whether investment in participatory biodiversity monitoring makes economic sense for obtaining data for management decisions, we compared the cost efficiency of participatory and conventional biodiversity monitoring methods in Philippine parks. We found that, from a government perspective, investment in monitoring that combines scientific with participatory methods is strikingly more effective than a similar level of investment in conventional scientific methods alone in generating conservation management interventions. Moreover, the local populace seemed to benefit from more secure *de facto* user rights over land and other resources. Participatory biodiversity monitoring not only represents a cost-effective alternative when conventional monitoring is impossible, but it is also an unexpectedly powerful complementary approach, capable of generating a much higher level of conservation management intervention, where conventional monitoring already takes place.

INTRODUCTION

Biodiversity monitoring is being increasingly relied upon to identify areas of conservation priority (1) and to guide site-based assessments of population change (2) and subsequent management interventions (3). Monitoring also provides critical biodiversity baselines by which progress in global policy objectives can be measured (4, 5).

Because biodiversity monitoring by professional scientists is often costly (6), at least relative to the budgets of most conservation agencies (7), it is largely undertaken in financially wealthy countries. Few monitoring schemes exist in the developing world, where the biological "hot spots" are concentrated.

Where the aim of monitoring is to obtain data for management decisions, alternative approaches that involve local people with little formal education are emerging (8–10). These approaches have some practices in common, including carrying out monitoring on a local scale (11) and directly involving local people in data collection.

It has been suggested that such approaches have considerable potential to complement professional monitoring in developing countries because they may be cheap relative to the costs of professional monitoring (11, 12). The paucity of quantitative data on the cost and effectiveness of monitoring has, however, constrained any systematic assessment.

The Philippine Government's scheme for monitoring protected areas provides a unique experimental setting in which to compare participatory methods of biodiversity monitoring with conventional scientific methods without the participation of local residents in order to assess their costs and specific impact on local management decisions. This monitoring scheme comprises two sets of simple methods: one that includes local residents in data collection and one that does not. The scheme is intended to improve the information available to decision-makers in parks through the regular collection of data on natural biological resources and their utilization. The focus is on identifying trends in the important biodiversity assets of an area and the use of the area's biodiversity in order to guide park management action.

MATERIALS AND METHODS

The two sets of monitoring methods were compared across 1.1 million ha of protected areas in the Philippines. One set comprised two methods that included 350 local people in data collection and/or discussion of data.

These methods were the focus group discussion method and the field diary method (13). The *focus group discussion* method involved establishment of volunteer community monitoring groups made up of 5–8 local residents who collected information on resource use, species populations, and habitat condition on a regular basis between quarterly discussions with protected-area staff. The members of the community monitoring groups were identified in cooperation with local community leaders so as to include the most experienced hunter–forest product gatherers and fisher-people in each village. This method was intended to indicate changes in perceived harvest volume per unit effort.

The *field diary* method included standardized recording of routine observations and records provided by local people of species, habitats, and human use of wild flora and fauna by protected-area staff in a simple pocketbook or on a data sheet during patrols. For each observation, the protected-area staff recorded the name of the observer, the date and the location of the observation, the species or human resource use observed, and the number of individuals or the quantity of resources used. This method was intended to indicate changes in the relative abundance of species and resource use.

The other set of methods was composed of standardized techniques that follow normal scientific requirements for objectivity and repeatability. These methods were the fixed point photography and the line-transect method. The methods were carried out by protected-area staff without the involvement of local communities.

The *fixed point photography* method consisted of taking on-the-ground fixed point photographs of selected hillsides in priority forest blocks at regular intervals. This method was intended to indicate changes in size of vegetation type blocks and in land-use of priority areas.

The *line-transect* method consisted of a line-transect survey of wildlife and resource use along permanent routes. This

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Table 1. Examples of monitoring results and conservation management interventions resulting from both participatory and conventional scientific biodiversity monitoring methods in Philippine protected areas.

Monitoring method	Example of monitoring result	Conservation management intervention emanating from the monitoring result
Focus group discussion	A community monitoring group reported a decline in the abundance of marine fish in Basco Bay of Batanes Island (Batanes Protected Sea and Landscape).	The municipality of Basco issued an ordinance allowing fishing with hook and line but banning the use of nets and compressors in the bay. The abundance of fish in the bay reportedly increased after only 7 months.
Field diary	Reports from local people of sightings of crocodile and the presence of crocodile hunters near San Mariano village (Northern Sierra Madre Natural Park).	The municipality of San Mariano issued an ordinance declaring the critically endangered Philippine crocodile *Crocodylus mindorensis* a municipal "flagship species" and establishing penalties for violation of previous ordinances intended to protect this species.
Fixed point photography	A new photo of a forested hill tract in the protected zone of the park showed that a swidden had been opened (Mt. Kitanglad Range Natural Park).	Park staff showed the before and after photos to the head of the village. He obtained a promise from the violators not to extend the swidden without permission from the protected-area management council.
Line transect	Fewer records of giant clams (Tridacnidae) than before on the transect swim routes in the sustainable-use zone (Apo Reef Natural Park).	The park staff raised awareness among local fishermen of the existing regulations on giant clam collection via the local radio and in person with fishermen when they requested permits to fish inside the park. In addition, staff requested assistance from a university on how to propagate the species and thus restock the wild population.

method was intended to indicate changes in wildlife population size, human intensity of resource use, and/or shift in range of wildlife/human resource extraction.

In each park, the monitoring focused on a list of 10–15 taxa and 5–10 signs of resource use (examples in 14) selected by protected-area staff in cooperation with local community members and staff of the National Protected Areas and Wildlife Bureau. Data were collected every three months with the exception of field diary data, which were compiled whenever rangers were in the field.

The data organization and analysis were undertaken locally by the protected-area staff. The importance of decision-making and management action was emphasized in the training activities and in the way the standard format for progress reporting was structured. In addition, the management councils of the protected areas were encouraged to include regular presentation and discussion of analyzed results and proposed actions in their annual work plans.

Both sets of methods were simple protocols that required only relatively little training and instruction. When the monitoring scheme was designed, these methods were selected specifically because they were field-based, possible to use in areas where specialist staff is lacking, and believed to be cost-effective (rationale for choice of methods described in 13).

The effectiveness in terms of conservation impact of biodiversity monitoring was examined in eight protected areas (Apo Reef, Bataan, Batanes, Northern Sierra Madre, Mt. Apo, Mt. Kanlaon, Mt. Kitanglad Range, and Siargao). These areas each contain 0 to 85 000 residents (mean = 21 200) who depend heavily upon forest and coastal resources, including wildlife (15). The sites were chosen on the basis of *i)* their combined coverage of Philippine flora and fauna, *ii)* the interest of protected-area communities in cooperating with government staff on resource management, *iii)* legislative status and field personnel available, *iv)* coverage of the administrative regions of the government, and *v)* the law and order situation. The protected areas were established pursuant to the National Integrated Protected Area System Act (16), which provides communities resident inside or adjacent to the areas with access and rights over some use of forest/wetland resources plus representation in a protected-area management council. This is important, since few local people would be interested in volunteering to monitor biodiversity if they had no rights over some use of resources. Protected-area staff generally held first degrees in forestry or an associated field and had received training in biodiversity monitoring (and other aspects of protected-area management). The two sets of monitoring methods were in operation in all eight protected areas.

Conservation impact is difficult to measure by a standard scale across different habitats, and the true impact may only be discernible in the long term (14). We therefore used conservation management interventions as proxy values for the conservation impact.

We defined a "conservation management intervention" as a purposeful action by a managing body to conserve or achieve a more sustainable use of the biological resources. Examples of management interventions are provided in Table 1. Several monitoring methods sometimes simultaneously led to one intervention. For instance, eroded hillsides revealed by fixed point photography and overgrazing by goats of the same area reported by a community monitoring group both led to the organization of a workshop to develop a local pasture management plan. At other times, data indicated that environmental conditions were stable or improving, and this usually did not lead to any management intervention.

The usefulness of the interventions and whether they had actually been carried out was examined by discussions with protected-area staff and local community members and by cross-checking with the minutes of protected-area management council meetings and other written documentation. Decisions that did not lead to action and those that were only part of the management system (e.g., improve functioning of protected-area council) were omitted from the analysis.

Other written documentation with which we compared the monitoring data included previously published studies (15, 17, and 18) and the following unpublished materials: Department of Environment and Natural Resources (DENR) Integrated Protected Area System management plans; technical reports of DENR, Nipa, and the Conservation of Priority Protected Areas Project on local government administration, park management, human use, indigenous people, marine resources, vegetation, flora, butterflies, shellfish, marine turtles, birds, mammals; DENR protected-area suitability assessments; and semiannual World Bank supervision-meeting briefing materials and aide memories 1996–2002.

We included conservation management interventions undertaken between December 1998 and July 2001 (n = 156; see 19). Management interventions were undertaken in the protected areas of Apo Reef (7 interventions), Bataan (10), Batanes (16), Northern Sierra Madre (28), Mt. Apo (21), Mt. Kanlaon (13),

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Table 2. Cost per conservation management intervention resulting from participatory and conventional scientific biodiversity monitoring methods in Philippine protected areas.

Monitoring method	Travel (USD y^{-1})	Materials* (USD y^{-1})	Equipment† (USD y^{-1})	Park staff time‡ (USD y^{-1})	Total cost (USD y^{-1})	Total no. of interventions	Cost per intervention (USD)	No. of interventions targeting key threats	Cost per intervention targeting key threats (USD)	No. of interventions leading to policy change	Cost per intervention leading to policy change (USD)
Focus group discussion	6952§	400	0	6600	13 952	89	418.0	38	979.0	52	715.5
Field diary	2680#	1000	1236	6000#	10 916	82	355.0	42	693.1	39	746.4
Fixed point photography	2573	1460	2228	5760	12 021	14	2289.7	8	4007.0	6	5342.7
Line transect	2626	1000	1540	5880	11 046	21	1402.7	6	4909.3	12	2454.7

Note: Based on 2001 data (54 Philippine pesos per US dollar [USD], December 2005); excluding expenditures on training/capacity building and time spent on monitoring by local community members. *Estimated cost of paper sheets, Xeroxing, identification materials, batteries, films, etc. †Based on 20% depreciation per year. When equipment was used for several monitoring methods in a protected area, the expenses were split between each method. ‡Estimated time used on field work, analysis, and reporting, based on the assumption that the same amount of time was used on analysis/reporting as on field work. §Including cost of community meetings. #Estimated expenses based on the assumption that 50 person-days were devoted to field work with the field diary method in each protected area every year; the amount of time spent was difficult to quantify because this method was designed to be carried out as an integral part of the patrolling.

Mt. Kitanglad Range (36), and Siargao (25). Before the monitoring scheme was established, the monitoring activity of park staff was largely restricted to regular assessment of the amount of extracted timber. Very few, if any, management interventions emanated from this.

We compiled data on conservation management interventions and reviewed written documentation on these at two national workshops on biodiversity monitoring with protected-area staff and during 62 field visits of 3–7 d each. In addition, we reviewed 316 protected-area council resolutions and 60 quarterly reports from local to central government for conservation management interventions. Data lumping across sites was possible because the same person scrutinized and evaluated all the interventions.

We used three variables to investigate the quality of the conservation management interventions taken: *i)* whether the interventions addressed the most serious threats to the protected areas' conservation values, *ii)* whether they resulted in policy change, and *iii)* whether they addressed the resource use by local resident people or outsiders. If interventions do not address the greatest threats, the activities probably waste scarce conservation resources. If the interventions do not lead to policy change within local government and community institutions, they are unlikely to have a lasting impact (see also 14, p. 2643). If the interventions only target a limited group of resource users, the problem identification may be incorrect. For instance, monitoring methods based on the involvement of local residents may not be useful if they only lead to actions intended to control the resource use by people from other places.

We defined "threats" as the human activities with the most negative impact on the areas' conservation values. Based on existing information on each park from other sources, the three most serious threats of each site were identified as industrial and road development (four sites), logging and timber poaching (four sites), small-scale agriculture (four sites), large-scale agriculture (three sites), and commercial marine fishing (three sites), along with gathering of nontimber forest and wetland products, grazing, wildlife hunting, and quarrying (one site each). Even if the main threats to each area are known, monitoring is important to guide detailed decision-making. We defined "policy change" as new resolutions, ordinances, bylaws, or guidelines. We defined "outsiders" as people not living in or adjacent to the protected area.

The number of conservation management interventions was compared between the four methods using chi-square tests (20). When interventions were associated with the simultaneous use of several monitoring methods, they were attributed to each method (as each method alone was in other instances sufficient to trigger an intervention).

RESULTS

Our data on conservation management interventions show that, for approximately the same recurrent government investment (Table 2), far more interventions result from participatory biodiversity monitoring methods as compared with conventional scientific ones ($\chi^2_3 = 90.8$, $p < 0.01$; Fig. 1a). This pattern also holds if we restrict the analysis to those interventions that only target the three most serious threats to species populations and habitats at each site ($\chi^2_3 = 46.7$, $p < 0.01$; Fig. 1b). Moreover, if

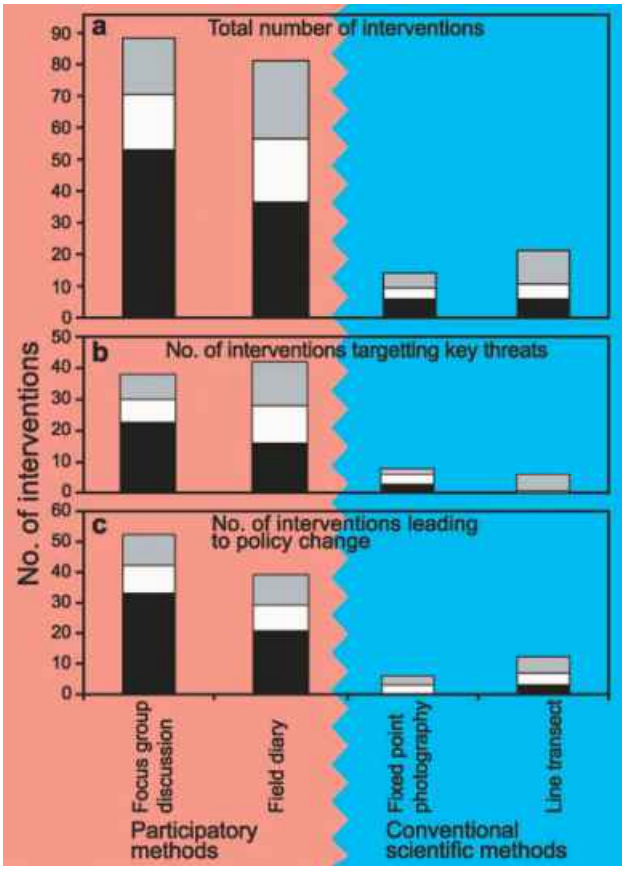

Figure 1. Effectiveness of participatory and conventional scientific biodiversity monitoring methods in generating conservation management interventions intended to improve the way local people (black), outsiders (white), and both (gray) manage Philippine protected-area resources. (a) The total number of interventions generated by each method. (b) The number of interventions that targeted the three most serious threats to the biodiversity of each site. (c) The number of interventions that led to policy change within local government and community institutions.

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we look at interventions that led to policy change with a potential long-term impact on sustainable development (i.e., new resolutions or bylaws), the same pattern emerges ($\chi^2_3 = 52.7$, $p < 0.01$; Fig. 1c).

This general difference held true whether we considered resources used by local people or by outsiders (Fig. 1a). It also holds true both if we look at interventions that target the most serious threats to each site's biodiversity (Fig. 1b) and those with a potential long-term impact (Fig. 1c). Our data suggest that participatory monitoring effectively generates conservation management interventions not only to address resource use by locals but also by people from other places.

DISCUSSION

To our knowledge, these are the most comprehensive data on conservation management interventions resulting from a developing country biodiversity monitoring scheme. However, they have three important limitations (described in 14 and summarized below). Firstly, the recorded interventions may not accurately reflect the actions taken. Some interventions may have been overlooked, particularly actions taken by community monitoring group members. In addition, a few interventions would perhaps have been taken even without the monitoring, e.g., as a result of community management by other initiatives in the same parks. The consistent application of the definition of management interventions also proved difficult on occasions, although the definition was intended to be clear, objective, and straightforward. This problem was minimized, however, by letting the same person scrutinize and evaluate all the interventions. Our assessment of the main threats to the parks' conservation values may also be biased by insufficient or inaccurate information on some of the parks (particularly Siargao) from other existing sources.

Secondly, we used conservation management interventions as surrogate information for the overall conservation impact. Since an intervention implies that somebody has taken an action intended to improve the conservation or sustainable use of resources, management interventions may have a conservation impact in the wider sense. The scale of the impact may, however, differ substantially from one intervention to the next (see examples in Table 1). In addition, although we know the interventions were made and that 98% of them were, or probably were, meaningful, justified, and soundly linked to the underlying observations (14), we do not know whether the interventions led to threat reduction on the ground. Further study would be required to assess the outcome of the interventions.

Thirdly, the monitoring methods were different not only in their degree of local participation but also in the conditions they measured (Table 1). Comparison of the same method with and without local participation was impossible because the focus group discussion method requires the involvement of local people. Additional environmental variables were not included because the study was part of a capacity-building program in which conservation, and not research, was the primary objective.

Despite these limitations, our results suggest that, from a government perspective, participatory biodiversity monitoring is more effective than conventional monitoring in terms of generating local conservation management interventions in Philippine protected areas (Table 2). The interventions seemed to be relevant for biodiversity conservation because a large proportion addressed the most serious threats to the biodiversity of the sites (Fig. 1b) and led to changes in local policies with potentially long-term impacts (Fig.1c). Community involvement in the participatory methods was entirely voluntary. We did not quantify the community's investment in time, but this investment was small. We also did not assess the initial costs of training and capacity-building. These costs were probably highest for the focus group discussion method. Facilitating discussions for the purpose of monitoring biodiversity was not as straightforward as the other methods (13) but required an independent way of thinking on the part of the park staff.

We do not know how general our findings are. The cause-effect linkages that the management interventions dealt with were in a large part relatively simple (Table 1). In Philippine parks, local people are, to a large extent, the *de facto* day-to-day managers of the biological resources, given their physical proximity to them and their often intimate knowledge of fauna, flora, and habitats (see also 21). The role of the government is limited due to its remoteness and persistent shortage of funds. In addition, in many parks, people maintain traditional community-based systems for controlling and monitoring access to certain sites and resource uses. Community leaders and people regularly discuss the availability and quality of natural resources. The participatory monitoring methods benefited from these existing informal monitoring systems. Our findings may be general to areas where the cause-effect and interventions operate in fairly simple ways (11), where the benefits to local people of involvement exceed the costs (6), and where the government embarks on shared management of resources with local people, and the authorities and local people therefore have a common interest in the parks' management objectives (see, e.g., 22, 23). On the other hand, in areas where changes, threats, or interventions operate in complex fashions, where rural people do not depend on the use of natural resources and there are no real benefits flowing to the local people from doing monitoring work, or where there is a poor relationship between the authorities and the local people (14, p. 2645), participatory methods are probably less likely to yield useful data and management solutions than conventional scientific approaches. The motivations for community members to participate in monitoring work are primarily linked to a number of important socioeconomic benefits of monitoring, which range from enhanced *de facto* user rights to land and resources, to local status, pride in an area, and potentially enhanced training opportunities (11). Participatory methods are only continued when local people benefit from participation in the monitoring (6). Monitoring schemes that simply offload the costs of monitoring onto the local communities without associated benefits are unlikely to be sustained (see also 24–26).

One may argue that the most important fact is that interventions to control land and resource use are being implemented, but, if the trends perceived by locals are false or the problem identification is incorrect, participatory methods may lead to incorrect decisions (27, 28). Few comparisons have been made about the accuracy of participatory and conventional methods (e.g., 29–32; review in 11), and their results are too inconsistent for firm conclusions to be drawn. Further scientific tests of the accuracy of participatory monitoring methods are therefore essential (33), particularly in the developing world where the potential for involving people with little formal education in biodiversity monitoring is especially high (10).

At the World Summit on Sustainable Development in 2002, countries agreed to ambitious targets for reducing biodiversity loss by 2010 (34, 35). If properly coordinated, participatory biodiversity monitoring could serve as a practical tool for generating management action, simultaneously complementing conventional monitoring and allowing an increase in sample size and area with which to assess progress toward these targets (36, 11). Our findings suggest that, at the protected-area level, participatory monitoring may not only represent a cost-effective

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alternative when conventional monitoring is impossible but also an unexpectedly powerful complementary approach that is capable of generating a much higher level of conservation management intervention where conventional monitoring is already taking place.

References and Notes

1. BirdLife International. 2004. *State of the World's Birds 2004: Indicators for our Changing World*. BirdLife International, Cambridge, UK, 73 pp.
2. Donald, P.F., Green, R.E. and Heath, M.F. 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. *Philos. T. R. Soc. Lon. B. 269*, 25–29.
3. Sutherland, W.J., Pullin, A.S., Dolman, P.M. and Knight, T.M. 2004. The need for evidence-based conservation. *Trends Ecol. Evol. 19*, 305–308.
4. Balmford, A., Green, R.E. and Jenkins, M. 2003. Measuring the changing state of nature. *Trends Ecol. Evol. 18*, 326–330.
5. Convention on Biological Diversity. 2005. The 2010 Biodiversity Target Indicators. (http://www.biodiv.org/2010-target/indicators.aspx)
6. Hockley, N.J., Jones, J.P.G., Andriahajaina, F.B., Manica, A., Rakoto, F.E., Ranambitsoa, E.H. and Randriamboahary, J.A. 2005. When should communities and conservationists monitor exploited resources? *Biodivers. Conserv. 14*, 2795–2806.
7. Bruner, A.G., Gullison, R.E. and Balmford, A. 2004. Financial costs and shortfalls of managing and expanding protected-area systems in developing countries. *BioScience 54*, 1119–1126.
8. Sheil, D. and Lawrence, A. 2004. Tropical biologists, local people and conservation: new opportunities for collaboration. *Trends Ecol. Evol. 19*, 634–638.
9. Bennun, L., Matiku, P., Mulwa, R., Mwangi, S. and Buckley, P. 2005. Monitoring important bird areas in Africa: towards a sustainable and scaleable system. *Biodivers. Conserv. 14*, 2575–2590.
10. Danielsen, F., Burgess, N.D., Balmford, A., Fjeldså, J., Andrianandrasana, H.T., Becker, C.D., Bennun, L., Brashares, J.S., et al. 2006. Monitoring matters: evaluating locally-based biodiversity monitoring in developing countries. *Oryx 40*, 14–15.
11. Danielsen, F., Burgess, N.D. and Balmford, A. 2005. Monitoring matters: examining the potential of locally-based approaches. *Biodivers. Conserv. 14*, 2507–2542. (http://www.monitoringmatters.org/cases/htm)
12. Danielsen, F., Mendoza, M.M., Alviola, P., Balete, D.S., Enghoff, M., Poulsen, M.K. and Jensen, A.E. 2003. Biodiversity monitoring in developing countries: what are we trying to achieve? *Oryx 37*, 407–409.
13. Danielsen, F., Balete, D.S., Poulsen, M.K., Enghoff, M., Nozawa, C.M. and Jensen, A.E. 2000. A simple system for monitoring biodiversity in protected areas of a developing country. *Biodivers. Conserv. 9*, 1671–1705.
14. Danielsen, F., Jensen, A.E., Alviola, P.A., Balete, D.S., Mendoza, M.M., Tagtag, A., Custodio, C. and Enghoff, M. 2005. Does monitoring matter? A quantitative assessment of management decisions from locally-based monitoring of protected areas. *Biodivers. Conserv. 14*, 2633–2652.
15. NORDECO and DENR. 1998. *Integrating Conservation and Development in Protected Area Management in Northern Sierra Madre Natural Park, the Philippines*. DENR, Manila, and NORDECO, Copenhagen, 207 pp.
16. Department of Environment and Natural Resources. 1992. *National Integrated Protected Area System Act* R. A. No. 7586 and *Implementing Rules and Regulations* DAO 25, Series of 1992. DENR, Manila, 38 pp.
17. NORDECO and DENR. 1998. *Integrating Conservation and Development in Protected Area Management in Bataan Natural Park, the Philippines*. DENR, Manila, and NORDECO, Copenhagen, 104 pp.
18. NORDECO and DENR. 1998. *Integrating Conservation and Development in Protected Area Management in Mt. Kitanglad Range Natural Park, the Philippines*. DENR, Manila, and NORDECO, Copenhagen, 138 pp.
19. Danielsen, F. 2007. (http://www.monitoringmatters.org/supportingmaterial/danielsen2007ambio)
20. Fowler, J. and Cohen, L. 1988. *Statistics for Ornithologists*. BTO Guide No. 22. British Trust for Ornithology, Norfolk, UK, 150 pp.
21. Getz, W.M., Fortmann, L., Cumming, D., du Toit, J., Hilty, J., Martin, R., Murphree, M., Owen-Smith, N., et al. 1999. Sustaining natural and human capital: villagers and scientists. *Science 283*, 1855–1856.
22. Stuart-Hill, G., Diggle, R., Munali, B., Tagg, J. and Ward, D. 2005. The event book system: a community based natural resource monitoring system from Namibia. *Biodivers. Conserv. 14*, 2611–2631.
23. Topp-Jørgensen, E., Poulsen, M.K., Lund, J.F. and Massao, J.F. 2005. Community-based monitoring of natural resource use and forest quality in montane forests and Miombo woodlands in Iringa District, Tanzania. *Biodivers. Conserv. 14*, 2653–2677.
24. White, S. 1996. Depoliticising development: the uses and abuses of participation. *Development in Practice 6*, 6–15.
25. Funder, M. 2005. Bias, intimacy and power in qualitative fieldwork strategies. *J. Transdisc. Envir. Stud. 4*, 1–9.
26. Cooke, B. and Kothari, U. (eds). 2001. Participation: The New Tyranny? Zed Books, London, UK, 207 pp.
27. Penrose, D. and Call, S. 1995. Volunteer monitoring of benthic macroinvertebrates: regulatory biologists' perspectives. *J. N. Am. Benthol. Soc. 14*, 203–209.
28. Brandon, A., Spyreas, G., Molano-Flores, B., Carroll, C. and Ellis, J. 2003. Can volunteers provide reliable data for forest vegetation surveys? *Nat. Areas J. 23*, 254–262.
29. Darwall, W.R.T. and Dulvy, N.K. 1996. An evaluation of the suitability of non-specialist volunteer researchers for coral reef fish surveys. Mafia Island, Tanzania: a case study. *Biol. Conserv. 78*, 223–231.
30. Hellier, A., Newton, A.C. and Gaona, S.O. 1999. Use of indigenous knowledge for rapidly assessing trends in biodiversity: a case study from Chiapas, Mexico. *Biodivers. Conserv. 8*, 869–889.
31. Noss, A.J. 1999. Censusing rainforest game species with communal net hunts. *Afr. J. Ecol. 37*, 1–11.
32. Uychiaoco, A.J., Arceo, H.O., Green, S.J., De la Cruz, M.T., Gaite, P.A. and Aliño, P.M. 2005. Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. *Biodivers. Conserv. 14*, 2775–2794.
33. Rodríguez, J.P. 2003. Challenges and opportunities for surveying and monitoring tropical biodiversity—a response to Danielsen et al. *Oryx 37*, 411.
34. United Nations. 2002. World Summit on Sustainable Development: Plan of Implementation. (http://www.johannesburgsummit.org/html/documents/summit_docs/2309_planfinal.htm)
35. Balmford, A., Bennun, L., Brink, B.T., Cooper, D., Côté, I.M., Crane, P., Dobson, A., Dudley, N., et al. 2005. The Convention on Biological Diversity's 2010 Target. *Science 307*, 212–213.
36. Balmford, A., Crane, P., Dobson, A.P., Green, R.E. and Mace, G.M. 2005. The 2010 challenge: data availability, information needs and extraterrestrial insights. *Philos. Trans. R. Soc. Lon. B. 360*, 221–228.

37. Acknowledgments: We are very grateful to A. Balmford, N. Burgess, J. Fjeldså, M. Funder, C. Rahbek, T. Whitten, and M. Zint for comments on the manuscript; L. Anova, T. Blastique, N. Corpuz, M. Lim, V. Palaganas, W.S. Pollisco, and P. de los Reyes for help during data collection; an H. Hübertz, B. Kristensen, and B. Rubæk for other valuable assistance. We are also indebted to Danida (104.GEF.2 and 104.Dan.8–1203) and the Protected Area and Wildlife Bureau of the Department of Environment and Natural Resources for funding and to the World Bank for administrating the work.
38. First submitted 20 December 2005. Accepted for publication 18 December 2006.

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APPENDIX XIX

Danielsen, F., Jensen, A.E., Alviola, P.A., Balete, D.S., Mendoza, M.M., Tagtag, A., Custodio, C. and Enghoff M. 2005.
Does monitoring matter? A quantitative assessment of management decisions from locally-based monitoring of protected areas.
Biodiversity and Conservation 14: 2633–2652.

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Biodiversity and Conservation (2005) 14:2633–2652
DOI 10.1007/s10531-005-8392-z
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Does monitoring matter? A quantitative assessment of management decisions from locally-based monitoring of protected areas

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Received 14 April 2004; accepted in revised form 30 November 2004

Key words: Community-based natural resource management, Decision-making, Locally-based monitoring, Participatory monitoring, Philippines, Sustainability

Abstract. Biodiversity monitoring is criticized for being insufficiently relevant to the needs of managers and ineffective in integrating information into decision-making. We examined conservation management interventions resulting from 2½ years of monitoring by 97 rangers and 350 community volunteers over 1 million hectares of Philippine protected areas. Before this monitoring scheme was established, there was little collaboration between local people and park authorities, and park monitoring was restricted to assessments of the quantity of extracted timber. As a result of the scheme, 156 interventions were undertaken in terrestrial, marine and freshwater ecosystems. In total 98% of these interventions were meaningful and justified, 47% targeted the three most serious threats to biodiversity at the site, and 90% were implemented without external support, suggesting that the interventions were relevant and could be sustained over time at the local level. The mean time from sampling to decision-making was only 97 days, probably because 82% of the interventions were initiated by the same people and institutions that had compiled the underlying data, bypassing potential government bureaucracy. Many of the interventions were jointly undertaken by community members and the management authorities or consisted of local bylaws in support of park management. As a result of the monitoring, indigenous resource use regulation schemes were re-established with government recognition in several parks. The monitoring led to more diversified and realistic management responses on the part of the authorities, including a more socially acceptable and effective approach to enforcement. Of the four field monitoring techniques used, the most participatory one generated more interventions aimed at ensuring a continued resource supply for local communities ($\chi^2_3 = 69.1$, $p < 0.01$). Although this suggests that the interest of community members is associated with their possibilities to influence the flow of ecosystem goods and services, the 156 interventions targeted, directly or indirectly, all known globally threatened species of mammals, birds and butterflies in the parks.

Introduction

Biodiversity monitoring is claimed to be ineffective at integrating information into decision-making and insufficiently relevant to the needs of land and resource

managers (Danida 2000; Sheil 2001). The accuracy of these claims is of critical importance to policy and funding decisions. Committing resources to the design and operation of a monitoring system is a long-term and ongoing investment with outcomes only evident years into the programme (Watson and Novelly 2004). Those who are funding and/or implementing monitoring need to be confident that the monitoring is effective in achieving its objectives. Past assessments of monitoring initiatives have focused on their ability to detect trends (e.g., Thompson et al. 1998; Yoccoz et al. 2001; see also Brashares and Sam 2005; Hockley et al. 2005 (this issue)) but none has, to our knowledge, provided a quantitative assessment of effectiveness in terms of capacity to lead to conservation interventions on-the-ground, which is the goal of conservation efforts.

In this paper, we examine a simple monitoring scheme established by the Philippine government with project funding support in protected areas and used by rangers and community members with little formal education. This scheme is intended to improve the information available to decision-makers in parks through the regular collecting of data on natural biological resources and their utilisation. The focus is on identifying trends in the important biodiversity assets of an area and the use of the area's biodiversity in order to guide action in park management.

The monitoring scheme comprises four field methods: (1) focus group discussions with volunteer 'community monitoring groups' of particularly knowledgeable forest product gatherers, hunters and fishers; (2) systematic observations of wildlife and resource use during regular patrols (field diary method); (3) fixed point photography of selected hillsides; and (4) simplified line transect surveys (Danielsen et al. 2000). Philippine protected areas are obliged to carry out this monitoring as part of their routine park operations (DENR 2000; 2001). In each park, the monitoring focuses on a list of 10–15 taxa and 5–10 signs of resource use, selected by protected area staff in cooperation with local community members and staff of the national Protected Areas and Wildlife Bureau. Most lists include taxa of large terrestrial mammals, easily identifiable birds, crocodiles, marine turtles, fish and shellfish. Data are collected every 3 months with the exception of field diary data, which are compiled whenever rangers are in the field. The analysis is undertaken locally by the protected area staff. The scheme is entirely paper based but the information generated is possible to analyze using digital technology.

We explore whether this monitoring scheme is leading to conservation. By 'conservation' we mean the use of biological resources in such a way as to ensure their continuing availability for future generations. We use conservation management interventions as a surrogate measure of conservation impact. We also explore the time from data sampling to management action, who took actions on the basis of this monitoring, what kind of actions were taken, and the benefits of the individual field techniques. In addition, we assess whether recurrent funding for this scheme can be seen as a burden for the Philippine government, and we describe the status of the scheme 3 years after external support ceased.

Study areas

The biodiversity monitoring scheme has been established in protected areas at Apo Reef, Bataan, Batanes, Northern Sierra Madre, Mt. Apo, Mt. Kanlaon, Mt. Kitanglad Range and Siargao, the Philippines. The mean number of staff in the protected areas was 13. Staff members generally held first degrees in forestry or an associated field and had received training in biodiversity monitoring and other aspects of park management. Mean annual funding of the protected areas was 1.75 USD per ha (2001 data). These areas each contain 0–85,000 residents (mean = 21,200), who depend heavily upon forest and coastal resources to support their livelihoods (e.g. NORDECO and DENR 1998a; 1998b; 1998c). The protected areas were established pursuant to the National Integrated Protected Area System Act (DENR 1992), which provides resident communities with access and rights over some use of forest/wetland resources plus representation on a protected area management board (council). While people have been illegally exploiting the resources in the past, they are now allowed to undertake controlled harvesting in certain areas. This is important as it would otherwise be difficult to achieve the involvement of local communities in monitoring.

Methods

Conservation impact is difficult to measure on a standard scale across different habitats, and the true impact may only be discernible in the long term. We therefore used conservation management interventions as a proxy for conservation impact. We defined a 'conservation management intervention' as a purposeful action by a managing body to conserve or achieve a more sustainable use of the biological resources. The usefulness of the interventions and whether they had actually been carried out was examined by discussing them with protected area staff and local community members and by cross-checking with the minutes of protected area management board meetings and other written documentation. Decisions that did not lead to action and those that were only part of the management system (e.g. 'improve functioning of protected area council') were omitted from the analysis.

We assessed conservation management interventions undertaken in the parks between December 1998 and July 2001. We compiled data and reviewed documentation on the interventions at two national workshops on biodiversity monitoring with park staff and during 62 field visits of 3–7 days each. In addition, we reviewed 316 protected area council decisions and 60 quarterly reports on the results of the monitoring sent from local to central government.

We explored the relevance and sustainability of the conservation management interventions by:

(1) Comparing data on each intervention with existing information on each park from other sources and assessing whether the interventions were

meaningful, justified and soundly linked to the underlying observations. We defined 'meaningful interventions' as those with rational objectives, according to the socio-cultural, ecological and administrative contexts. We defined interventions that were 'justified and soundly linked to the underlying observations' as those which were appropriate in terms of target, intensity, timing and extent. Other important sources with which we compared the monitoring data included NORDECO and DENR 1998a, 1998b, 1998c and the following unpublished materials: DENR Integrated Protected Area System management plans; technical reports of DENR, Nipa and the Conservation of Priority Protected Areas Project on local government administration, park management, human use, indigenous people, marine resources, vegetation, flora, butterflies, shellfish, marine turtles, birds, mammals; and semi-annual World Bank supervision meeting briefing materials and aide-memoires 1996–2002.

(2) Examining whether the interventions addressed the three most serious threats at each site. We defined threats as the human activities with the most negative impact on the areas' conservation values. Based on existing information on each park from other sources, the main threats were identified as industrial and road development (4 sites), logging and timber poaching (4 sites), small-scale agriculture (4 sites), large-scale agriculture (3 sites) and commercial marine fishing (3 sites), along with gathering of non-timber forest and wetland products, grazing, wildlife hunting and quarrying (1 site each).

(3) Assessing the financial and institutional sustainability of the interventions by examining whether they depended on support from the outside, beyond the provincial level, or not.

We investigated the objective of the conservation management interventions by assessing whether they were primarily aimed at protecting natural habitats or particular species or at ensuring a continued supply of natural resources for local human communities. Some of the interventions simultaneously addressed more than one of these objectives. The number of interventions was compared between the four methods using chi-square tests (Fowler and Cohen 1988). Some interventions were associated with the simultaneous use of several monitoring methods, in which case they were attributed to each method (as each method alone was in other instances sufficient to trigger an intervention).

The species interventions were examined in more detail. We assessed whether they targeted globally threatened species by comparison with existing distributional and conservation status data on terrestrial mammals (Heaney and Mallari 2002), resident birds (Collar et al. 1999; Mallari et al. 2001; supplemented with Kennedy et al. 2000), and butterflies (Danielsen and Treadaway 2004).

We then identified the type of intervention (e.g. raising of awareness, establishment of bylaws governing resource use etc.), and who collected the data and took action (park staff, community members, municipal staff, etc.). In addition, we looked into whether the interventions addressed resource use by

local resident people or outsiders. We defined 'outsiders' as people not living in or adjacent to the protected area.

In order to examine the speed with which decisions were taken, we assessed the time from data sampling to decision-making for each intervention. Finally, we investigated the importance of the underlying data for the decision-making process by assessing whether the interventions were based on new data or not. We defined 'new data' as data not previously known to the senior local park staff or ourselves. Information on the status of the scheme in 2004 was obtained from a national workshop on biodiversity monitoring with park staff and by correspondence with each park.

Results

Relevance and sustainability of the management actions

Before the present monitoring scheme was established, the monitoring activity of park staff was largely restricted to regular assessment of the amount of extracted timber. Very few if any management interventions emanated from this. After 2½ years, the monitoring scheme had led to 156 documented conservation management interventions. These interventions addressed threats from a broad spectrum of activities, especially fishing (15% of 156 interventions), hunting (15%), gathering of non-timber forest products (14%), small-scale logging (13%) and shifting agriculture (10%) but also large-scale commercial logging and farming, quarrying and industrial development.

We examined the usefulness of these interventions and found that most (98%) of them were, or probably were, meaningful and justified and soundly linked to observations of changes in the occurrence of species/resource use. Three interventions did not fulfil this requirement. Two of these included the establishment of village bylaws that banned cutting of 'narra' (*Pterocarpus* sp.) and electro-fishing by outsiders, both in response to community monitoring group data that indicated a decline in the local catch of freshwater fish. Villagers argue that floating of fresh 'narra' on rivers impacts on fish populations but, to our knowledge, this linkage is as yet unproven (although forest degradation may well lead to increased siltation and declines in the diversity and abundance of fish). Likewise, banning only outsiders' non-selective fishing is irrational. The third intervention was a municipal ordinance to establish a crocodile rescue centre in response to field diary records of unsustainable hunting of the critically endangered Philippine crocodile *Crocodylus mindorensis*. A rescue centre is unlikely to reduce the threat to crocodiles from hunting (although long term awareness-raising associated with a rescue centre may generate local support for conservation of reptiles).

Moreover, we found that 73 (47%) of the interventions targeted the three most serious threats to each site's biodiversity. Furthermore, 140 (90%) of the 156 interventions were undertaken without financial, staffing or other

institutional support from the outside beyond the provincial level; the remaining interventions depended on funds for establishing income-generating initiatives (12 interventions) or on applied research and training on the part of national institutions (4).

Our findings suggest that locally relevant and sustainable management interventions emanated from the scheme; but were these actions taken in order to protect the biodiversity values or the supply of resources to the local people, and which monitoring technique did they emanate from?

Habitat interventions

We explored the purpose of the interventions and found that 79 of the 156 interventions were aimed at protecting natural habitats, whereas 61 were aimed at protecting particular species and 63 at ensuring a continued supply of biological resources for local human communities.

Among the 79 habitat interventions, most were targeted at forests (77%), coastal areas (14%) and grasslands (4%). The forest habitat interventions mainly addressed small-scale logging and shifting agriculture and focused on enforcement, raising awareness about resource management, and coordination between government agencies.

Far more habitat interventions emanated from the focus group discussion and field diary methods than from the fixed point photography and transect methods ($\chi^2_3 = 53.2$, $p < 0.01$; Figure 1a). This result holds both when we look at interventions to address local peoples' resource use and resource use on the part of outsiders (Figure 1a).

Species interventions

Moving from habitats to species, 48 of the 61 species interventions were focused on specific taxa, including eight that are globally threatened (Table 1) whereas 13 species interventions were targeted at species found within a certain area and habitat, or species with a specific local use (medicinal plants, non-timber forest products). Most of the species interventions addressed threats from local people, particularly hunting, and comprised awareness-raising and enforcement, but at least 10 other types of management activity were also involved. Most of these interventions emanated from the focus group discussion and field diary methods ($\chi^2_3 = 28.7$, $p < 0.01$; Figure 1b).

How many of the globally threatened species in the parks were targeted by the species interventions? To examine this, we compared data on the interventions with existing published data on the distribution and conservation status of three of the better known taxonomic groups. The parks are known to hold or probably hold populations of 68 globally threatened species of terrestrial mammals (17 species), resident birds (34), and butterflies (17). Only five

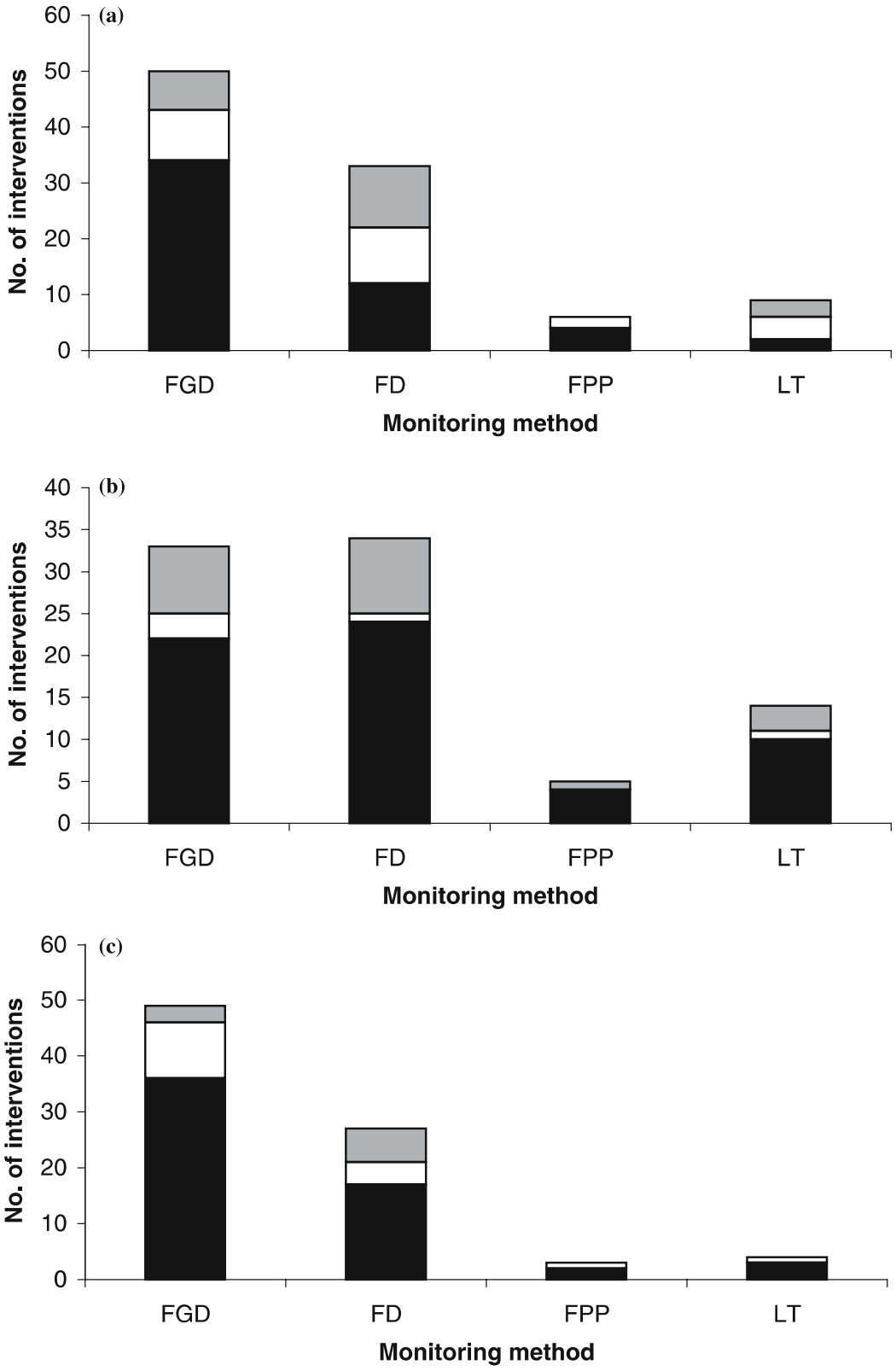

Figure 1. Effectiveness of the monitoring methods in generating conservation management interventions intended to improve the way local people (black), outsiders (white) and both (grey) manage the resources. (a) The number of interventions aimed at protecting natural habitats. (b) The number of interventions aimed at protecting particular species. (c) The number of interventions aimed at ensuring a continued supply of natural resources for local human communities. Abbreviations are: FGD, focus group discussion; FD, field diary; FPP, fixed point photography; and LT, line transect.

Table 1. Taxa targeted by management interventions emanating from the monitoring and aimed at protecting particular species, including their conservation status, local use, the origin of the threat to the population of the species, and the type of intervention.

Taxa	Latin name	Category IUCN[a]	Local use	Threat from local or outsider[b]	Type of intervention[c]
PLANTS					
Trees			Multiple	OL	Awa, coo, enf
Rattan	*Calamus* spp.		Food, house construction, medicinal, furnituremaking, handicraft	L	Awa, coo, enf, par
Orchid			Ornamental	L	Awa, coo, enf, liv, par
ARTHROPODS					
Tetanus beetle			No information	O	Enf
Butterflies	Rhopalocera		Pollinator of crops and fruit trees, ornamental	O	Enf
SHELLFISH					
Giant clam	Tridacnidae	LR-cd	Food, lime for betel chewing, garden decoration, animal feeding troughs	OL	Awa, enf, par, res
Giant triton	*Charonia tritonis*		Ornament, food	L	Awa, byl, coo, par
Coconut crab	*Birgus latro*	DD	Food	L	Awa, byl, san, sea, siz
FISH					
Coral reef fish			Food	OL	Enf
Freshwater fish			Food	L	Coo, liv
REPTILES					
Green turtle	*Chelonia mydas*	EN	Food (meat, eggs) and sold for cash (meat, eggs, carapace)	OL	Awa, coo, enf, san
Hawksbill turtle	*Eretmochelys imbricata*	CR	Food (meat, eggs) and sold for cash (meat, eggs, carapace)	OL	Awa, coo, enf, san
Estuarine crocodile	*Crocodylus porosus*		Food (eggs), dog food (juveniles), superstitious belief	L	Awa, byl, coo, enf, oth, par, san

Philippine crocodile	*Crocodylus mindorensis*	CR	No information	L	Awa, byl, coo, enf, oth, par, san
BIRDS			Food	L	Par, san
White-bellied sea eagle	*Haliaeetus leucogaster*		Food	L	Awa, enf
Philippine eagle	*Pithecophaga jefferyi*	CR		OL	Awa, coo, enf, par, san
MAMMALS					
Golden-crowned flying fox	*Acerodon jubatus*	EN	Food	L	Awa, coo, per
White-winged flying fox	*Pteropus leucopterus*	EN		L	Awa, coo, per
Philippine warty pig	*Sus philippensis*	VU	Food, sold for cash, body ornament (teeth)	L/OL	Awa, byl, coo, enf, ext, sea
Philippine brown deer	*Cervus mariannus*	DD[d]	Food, cash source (meat, antlers), home ornament, internal organs used to treat stomach ache, antlers used to treat measles	L	Awa, byl, coo, sea
Dolphin	Cetacea		Food	L	Awa
Dugong	*Dugong dugon*	VU	Food, cash source, body ornament, amulet (tusks). Tusks are used for medicine	L	Awa
Philippine tarsier	*Tarsius syrichta*	DD	Burnt fur used for convulsion	L	Awa, enf

[a]Using the criteria of IUCN (2003): CR, critically endangered; EN, endangered; VU, vulnerable; LR-cd, lower risk-conservation dependent; DD, data deficient.

[b]Outsider defined as 'people not living in or adjacent to the protected area'. L, local; O, outsider.

[c]Intervention type abbreviations are: Awa, awareness-raising; byl, bylaws at tribal, village or municipal level; coo, cooperation between authorities; enf, enforcement of existing regulations; ext, extraction method ban; liv, livelihood assistance; oth, other type of intervention; par, Protected Area Management Board resolution; per, permit system establishment; res, research; san, sanctuary establishment; sea, seasonal closure; siz, size-limit for harvesting.

[d]Should be classified as globally threatened according to Heaney and Mallari (2002).

of the larger and more obvious of these species (Philippine eagle *Pithecophaga jefferyi*; and four mammal species) were the direct object of taxa-specific interventions, however the remaining 62 species were all indirectly targeted by other interventions emanating from the monitoring, especially habitat interventions to protect forests (61 species) and wetlands (one species, *Anas luzonica*). Most of the threatened species in the parks suffer from degradation and destruction of their forest habitat.

While only the larger and relatively easily identified threatened species in the parks were directly targeted by species specific interventions, the scheme provided data on 47 taxa listed in the appendices of the Convention on the International Trade in Endangered Species (11 taxa in App. I; 35 taxa in App. II) and 75 globally red-listed taxa of plants (21 taxa) and animals (54 taxa), including 15 critically endangered, 13 endangered and 20 vulnerable taxa (NORDECO and DENR 2002). Some of these data have been reported to international agencies and may contribute to future management interventions.

Resource supply interventions

Among the 63 interventions aimed at ensuring the continued supply of resources, 74% dealt with particular resources, especially taxa of plants (15 interventions), marine fish and shellfish (12) and freshwater fish (11), and the remaining dealt with protected area or forest resources in general. Most resource supply interventions emanated from the focus group discussion method ($\chi^2_3 = 69.1$, $p < 0.01$; Figure 1c). This result holds both when we look at interventions to address local people's resource use and resource use on the part of outsiders (Figure 1c).

Who took action?

Before the present monitoring scheme began, there were few attempts to involve local people in the management of the parks, even though legislation (DENR 1992) allowed for it. To explore whether the scheme had made a difference, we examined who took action on the basis of the monitoring.

The point of departure of the monitoring scheme was that the protected area council would take decisions on the basis of the findings from the park staff's data analysis but, in reality, decisions were taken at four different levels: by protected area staff (83% of 156 interventions), local community members (49%), the protected area councils (44%), and government institutions at village and municipal level (19%).

Community action was mobilised particularly effectively by one of the monitoring techniques, the focus group discussion. A total of 62 of the 76 interventions made by local community members emanated from this method. Moreover, 70% of the 89 management interventions generated overall by this

method were undertaken by local communities (the corresponding figures for the other methods were 21–29%).

When we looked at the ability of the techniques to generate joint government/community member interventions, we also found that the focus group discussion method was the most effective ($\chi^2_3 = 74.8$, $p < 0.01$; Figure 2).

Type of activities included in the interventions

We then examined the type of intervention activity emanating from the monitoring. We found that the most frequent activities were raising awareness about resource management (69% of 156 interventions), strengthening the coordination between protected area stakeholders (49%) and enforcement of restrictions on access and resource use (50%). Most of the 78 enforcement interventions comprised enforcement in parallel with awareness-raising or other activities. Only 22 interventions involved enforcement in isolation, and these were mainly targeted at outsiders.

Many of the interventions involved policy-making within local government and community institutions. A total of 58 (37%) of the 156 interventions involved the issuing of resolutions or other policy-making on the part of the protected area councils. These interventions mainly emanated from the field diary and focus group discussion methods.

Local bylaws governing resource use were the focus of 35 (22%) of the interventions; these were mainly established by indigenous people, villages and municipalities. It is our experience that local bylaws are usually more effective in changing people's behaviour than national Philippine laws. Thirty of these

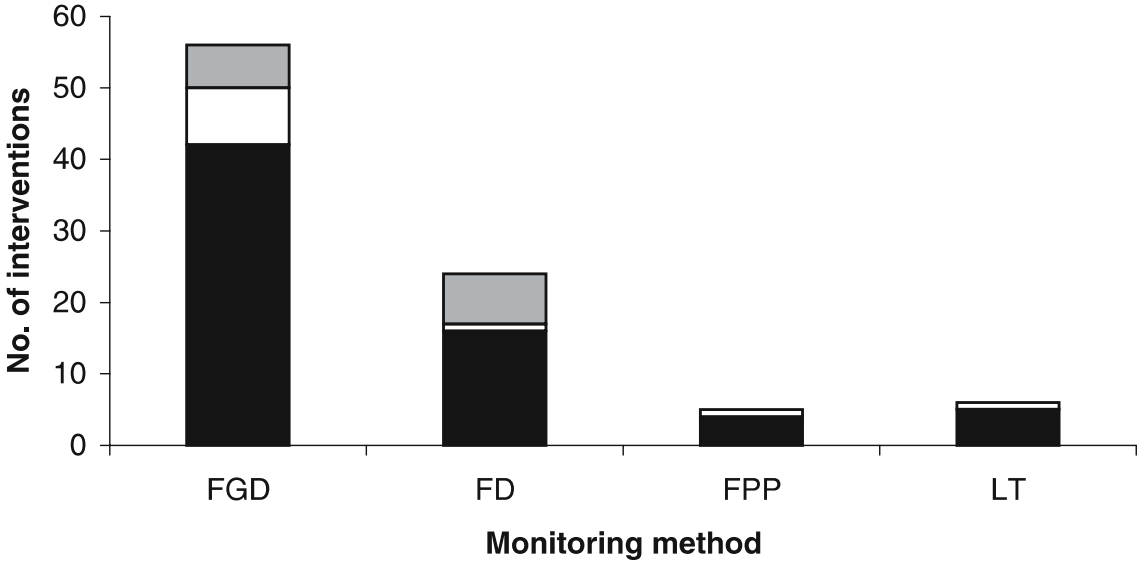

Figure 2. Effectiveness of the monitoring methods in generating joint government/community member interventions intended to improve the way local people (black), outsiders (white) and both (grey) manage the resources. Abbreviations are: FGD, focus group discussion; FD, field diary; FPP, fixed point photography; and LT, line transect.

35 bylaw interventions were generated at the initiative of members of the community monitoring groups, as part of the focus group discussion method. These actions were primarily taken to ensure a continued supply of resources for local people (22 interventions) rather than to protect species (11) or habitats (10) but they almost certainly also had a positive impact on both habitats and populations. The majority of the bylaw actions addressed threats from local people's activity (27 of 35 interventions). The main human activities addressed were fishing, hunting and gathering of non-timber forest products.

Time from data-collection to decision-making

To explore the efficiency of the scheme in integrating information into decision-making, we examined the speed with which management decisions were taken on the basis of this monitoring. We found that the average time from data sampling to decision-making was 97 days (for the 154 interventions with available data). The response time varied from 89 days (average for the field diary method) to 122 days (the transect method). The short response time can probably be explained by the fact that most interventions were implemented by the very same people and institutions that had compiled the underlying data: 61 (69%) of the 89 interventions generated by the focus group discussion method were partly or fully implemented by members of the community monitoring groups, indigenous people or local villages. Likewise, 74 (90%) of the 82 interventions generated by the field diary method were partly or fully implemented by the head of the protected area and his staff. The corresponding figures for the transect and photo documentation methods were 95% (of 21 interventions) and 79% (of 14).

Is the dialogue more important than the data?

Just how important are the data for decision-making? Is it the stakeholder dialogue prompted by the monitoring activity rather than the monitoring information that encourages action? To test this, we examined whether the underlying data for each intervention were new. A total of 139 (89%) of the 156 interventions were based, or probably based, on new data on the occurrence of species, resource use or threats not previously known to senior local protected area staff or the authors, indicating that the collecting of data is vital for decision-making.

Benefits of the individual methods

Our findings suggest several important, previously neglected characteristics of the four monitoring techniques used in this scheme. The focus group discussion

method was strikingly powerful at generating local bylaws, joint government/community actions (Figure 2) and interventions to ensure a continued supply of resources for local communities (Figure 1c), suggesting that this method may be very important in areas where the management objectives include sustainable resource use by local people. One weakness is that the success of the method is context-specific: in areas (such as Bataan Natural Park) with poor relationship between the authorities and the local people, this method is less effective.

The field diary method was powerful at generating management intervention to protect natural habitats and particular species (Figures 1a and b), and its effectiveness was less dependent on the local social context. Another advantage of this method is that it is simple and easy to grasp, even for people without training.

The simplified ranger-implemented transect method was capable of providing data for analysis of vertebrate population trends on a larger-scale (see Figure 1 in Danielsen et al. 2005 (this issue)), whereas the fixed point photography method was particularly useful for generating convincing inputs to local level awareness-raising and education work.

Linkage to national level

Every 3 months, the head of each park prepares a report to the protected area council. This report is copied to the Protected Area and Wildlife Bureau (PAWB) at national level. The report is structured such as to encourage park staff to both organize, analyse and interpret the data as well as to propose specific conservation management interventions. The report includes the dataset, a list of important observations of observed changes in species and resource use, and a list of proposed management interventions with a description of the issue identified (e.g. 'conversion of forest for farming of vegetables'), the location and the proposed action to be taken by the protected area council.

The staff of the PAWB are supposed to regularly review the reports and provide feedback to the park staff in order to keep errors in the recording at an acceptable level and to assist the parks when national level action is required to back up local management interventions. It was also envisaged that the PAWB staff would extract data with which to prepare annual reports for the Secretary of the Environment. This work at national level, however, has suffered from underfunding and weak institutional support.

Discussion

Two important caveats apply to the use of conservation management interventions for quantitative assessments of the effectiveness of biodiversity

monitoring schemes. First, we do not fully know if the recorded interventions accurately reflect the actions taken on-the-ground. Data were collected from protected area staff and villagers, from places within the parks where we knew that the monitoring methods were being used. Some interventions may have been overlooked, particularly actions taken by members of the community monitoring groups. In addition, it is possible that a few interventions would have been taken even without the monitoring. The long time-frame over which data were collected could also potentially limit the accuracy of information, but this problem was minimised because 151 (97%) of the 156 interventions were supported by resolutions or other written documentation. Although the definition of management interventions was intended to be clear, objective and straightforward, its consistent application sometimes proved difficult, particularly when several management initiatives were taken simultaneously as a result of findings from the monitoring. This problem was minimised, however, due to the fact that all the interventions were scrutinized and evaluated by the same person. Our assessment of the usefulness of the conservation management interventions may also be biased by insufficient or inaccurate park information coming from other existing sources. Knowledge of the human use, habitats and species of Mt. Apo, Mt. Kanlaon and Siargao, in particular, is very limited.

Secondly, we used conservation management interventions as surrogate information for the overall conservation impact. Since an intervention implies that somebody has taken an action intended to improve the conservation or sustainable use of resources, management interventions may have a conservation impact in a wider sense. The scale of the impact can, however, differ substantially from one intervention to the next, both in space and in time. For instance, the impact of a tribal-level bylaw permanently banning the hunting by tribesmen of Philippine warty pig *Sus philippensis* during the breeding season is very different from the impact of protected area staff raising the awareness of villagers on the location of the park boundary, based on photos of infringing slash and burn agriculture. In addition, we know the interventions were made but we have limited information on their subsequent outcome i.e. whether the actions led to a reduction in the intensity of the threats, or arrested declines in the extent and biodiversity content of the natural habitats. For instance, the level of respect that local bylaws solicit among villagers may differ from one area to the next, even within the same protected area.

What worked and why?

Despite the limitations, this study demonstrates several important points. Firstly, the park staff and villagers' monitoring of biodiversity and resource use led to relevant and sustainable management actions to protect biodiversity and the flow of ecosystem benefits on a local scale in terrestrial (92 interventions), marine (28) and freshwater ecosystems (16). The regular collecting of data by

park staff and community members appeared to be a vital element in the decision-making process.

The fact that the data analysis was made and the management decisions taken within existing institutions at the local level probably encourages local ownership and increases the likelihood of successful management (see also Obura et al. 2002; Sheil and Lawrence 2004). On the other hand, the individual local management action often has limited impact beyond the local scale. Larger-scale impacts of the monitoring would, however, be possible if the data were also analysed nationally and the findings made available to national-level policy makers in an appropriate format (see Balmford et al. 2005; Danielsen et al. 2005 (this issue); Green et al. 2005) or if copies of the data were regularly submitted to existing international monitoring schemes (Loh et al. 2005; Roberts et al. 2005 (this issue)).

Secondly, the effectiveness of the monitoring in generating management action may be associated with the short response time, as a result of minimal institutional distance between data recorders, decision-makers and action takers. Most actions (82%) were taken by the very same people and institutions that had compiled the underlying data, bypassing potentially bureaucratic institutions and communication channels.

Thirdly, local people's interest in collecting data and participating in monitoring-based decision-making appears to be directly associated with their ability to influence the flow of ecosystem benefits because, among the four monitoring methods used, the most participatory one generated strikingly more interventions aimed at ensuring a continued supply of ecosystem goods and services to the local communities (Figure 1c; see also Hockley et al. 2005 (this issue)).

Although the level of public participation in the monitoring differed from site to site (Barcelona 2004), this monitoring scheme has shown how local people can in practice participate meaningfully in the management of protected areas, as indicated, e.g., by the high number of local bylaws generated in support of protected area management (35). Moreover, the perception of the monitoring as a credible and independent source of information as opposed to personal observations substantially changed the agenda of some of the protected area councils. Sensitive issues such as commercial logging by powerful local politicians inside protected zones began to be openly discussed.

The monitoring also provided concrete opportunities for indigenous people to be heard by the park authorities and for the authorities to benefit from indigenous knowledge. Indigenous community members were directly involved in the monitoring in six of the eight protected areas examined. Many of these people began reporting immediately and directly to the protected area head and rangers on matters such as violations of resource use regulations by outsiders. Likewise, in three of the sites, indigenous zoning and resource use regulation schemes were being re-established with local government recognition and indigenous people were increasingly being recognized as resource co-managers.

The management interventions emanating from the monitoring involved a wide range of activities. The proportion of the 156 interventions involving enforcement (50%), and the fact that most of these actions were combined with other activities such as awareness raising, suggests that locally-based monitoring has not reduced the level of enforcement but that its use is now built on a greater acceptance and consensus among the local people. In support of experiences from Madagascar (Andrianandrasana et al. 2005 (this issue); and J. Durbin in litt.), our findings indicate that locally-based monitoring has led to a more socially acceptable and effective approach to enforcement. Threats from slash and burn agriculture inside protected zones have traditionally been addressed by enforcement, frequently with minimal impact. Only one of the 15 interventions aimed at slash and burn agriculture comprised enforcement alone, suggesting that the monitoring may also have led to more diversified and maybe realistic management responses on the part of the authorities in the field.

Current information is insufficient to assess the extent to which the monitoring methods are able to detect true trends in the abundance of species and resource uses. The worst case scenario is that the findings from the monitoring are outright wrong or misleading, that the actions are detrimental to conservation, and that the activities are wasting limited conservation opportunities and resources. Our findings showed, however, that 47% of the interventions targeted the three most serious threats to each site's biodiversity, and that almost all (98%) were, or probably were, well justified and meaningful. Important mechanisms for improving the validity of the data and for correcting mistakes in the scheme are the triangulation of results between the four methods, as well as the discussions with community members in the community monitoring groups and at the annual village meetings.

Cost

Is operation of this monitoring system prohibitively expensive? Philippine government expenditure on travel and materials (excluding equipment) was USD 16,500 per year (2001-data; 55 PhP per USD, July 2004). Government staff time devoted to field work related to the focus group discussion, fixed point photography and transect methods was 61 person-months. The time devoted to the field diary method was less than for the other methods but hard to quantify because this method formed an integral part of the patrolling. If we assume that roughly 10 person-months were devoted to fieldwork under the field diary method, that a similar time was used on analysis and reporting on field work for all the methods, and that an average government employee's salary is USD 150 per month, the approximate costs of government salaries for field work, analysis and reporting were USD 21,300 per year. With a total of 1.09 mill. ha of protected land and sea covered by this study, the average annual funding was USD 0.0151 per ha for travel and materials and USD

0.0195 per ha for government staff salaries, a total of USD 0.0346 per ha. This represents a mere 2.0 % of the average annual funding to Philippine protected areas, and is within the means of most developing country governments.

Status of the scheme in the Philippines

When this monitoring scheme was established, we considered it a feasible minimum starting point. If this minimum scheme could not be sustained over time then no biodiversity monitoring would be sustainable in the country.

Three years have passed since external involvement in the scheme ceased (December 2001). Despite the fact that the government's annual budget deficits have reached unprecedented levels, the scheme continues to be implemented in the majority of the sites where it was established but the efforts depend on the local availability of park staff and operational budgets.

The Protected Area and Wildlife Bureau has promoted the scheme as a standard management tool in protected areas (DENR 2000) and, as a result, the scheme has spread to new sites. Likewise, some parks have on their own initiative begun using the scheme (M. Mendoza pers. comm.). As of 2004, a total of 25 protected areas are using the scheme to the extent that the protected area councils and the heads of the protected areas make decisions and take actions on the basis of findings from the scheme (A. Tagtag in litt.). In addition, several NGOs, including the Foundation for Philippine Environment, Kabang Kalikasan ng Pilipinas, and the Soil and Water Conservation Foundation have adopted the methods and begun using them in new areas.

All four methods are still used but in some protected areas they have only one monitoring site for each method, clearly too little sampling effort to sufficiently inform management. In addition, in some of the new sites, the rangers have found it difficult to enlist the community's participation in the focus group discussions. This is especially demonstrated in the hesitance among some people to provide information and the non-attendance of others at the meetings of the community monitoring groups.

It appears that at the protected area level, in those parks where they have sufficient funds and staff for monitoring, there is a need for further training of park staff by the PAWB in participatory approaches, as well as in species identification, data analysis and application of the field methods in aquatic habitats. At the national level, there is a need to build further capacity in effectively making the locally-derived data available to national policy-makers.

Experiences with the scheme in other countries

Through experience exchange workshops and follow-on activities, the approach and lessons from this scheme have also spread to other countries. We know of concrete attempts to establish locally adapted versions of the scheme

in Indonesia, Laos, Tanzania, Nepal and Chile. In Indonesia, CARE staff tested the scheme in two national parks in Sulawesi in 2000. The scheme is still being used as part of the co-management system in one of these parks (G. Shea in litt.).

Parts of the scheme were established in the lowland forests and freshwater wetlands of Laos (Xe Pian, Champasak) and in the montane forest and miombo woodlands of Tanzania (Iringa District) in 2000 and 2002 respectively, building on efforts already being made by externally-funded protected area projects in these areas (experiences described in Poulsen and Luanglath 2005 and Topp-Jørgensen et al. 2005 (this issue)). Elements of the scheme are now being institutionalised within the Forestry sector in Tanzania.

In Nepal, the Department of National Parks and Wildlife Conservation and CARE Nepal attempted to establish the scheme in the heavily populated *terai* buffer zone of the Royal Bardia National Park in 2001 but the work had to be abandoned after the initial planning workshop because of insurgency in the area. In Chile, the scheme was established on a pilot basis in protected areas of Patagonia (Aysén, Region XI) in 2003 by the Corporación Nacional Forestal and the National History Museum of Santiago (D. Aldridge pers. comm.).

Evaluation criteria for the effectiveness of monitoring

Methods for monitoring biodiversity are usually evaluated only on the basis of their power to detect a trend in species abundance within a certain level of significance and not for their ability to impact management (an assessment of the statistical power of the transect method of the present scheme is provided in Danielsen et al. 2000; see also Brashares and Sam 2005; Hockley et al. 2005 (this issue)). While a management intervention is not an ideal measure of conservation impact, it may be useful from a conservation perspective because it encourages a holistic approach whereby monitoring is seen as an integrated aspect of management (see also Uychiaoco et al. 2005 (this issue)). The 'management intervention' unit is close to the end-point: conservation and sustainable resource use on-the-ground (see also Robertson and Hull 2001). Management interventions are, however, impossible to track through desk work but require concerted efforts in the field by experienced people. Our experiences suggest, however, that it is useful to track management interventions because they can indicate the possible management impact of the scheme and provide direction.

Acknowledgements

We are very grateful to A. Balmford, N. Burgess, J. Fjeldså and M. Poulsen for inspiring discussions. We thank N. Burgess, J. Fjeldså and T. Whitten for comments on the manuscript; L. Anova, T. Blastique, B. Christensen,

N. Corpuz, J. Durbin, P. Franks, M. Lim, N.A.D. Mallari, T. Manila, N. Moulinyawe, V. Palaganas, W.S. Pollisco, P. de los Reyes and E. Topp-Jørgensen for other assistance; the Protected Area and Wildlife Bureau of the Department of Environment and Natural Resources, and the Danish Government (Danida) for funding; and the World Bank for administrating the work. This paper is an expanded version of a presentation we made at a symposium on locally-based monitoring in Denmark in April 2004 (www.monitoringmatters.org). The symposium was organized by the Nordic Agency for Development and Ecology (NORDECO, Denmark) and the Zoology Department of Cambridge University (UK).

References

Andrianandrasana H.T., Randriamahefasoa J., Durbin J., Lewis R.E. and Ratsimbazafy J.H. 2005. Participatory ecological monitoring of the Alaotra wetland in Madagascar. Biodivers. Conserv. 14: 2757–2774.

Balmford A., Crane P., Dobson A.P., Green R.E. and Mace G.M. 2005. The 2010 challenge: data availability, information needs and extraterrestrial insights. Phil. Trans. R. Soc. Lond. B 360: 221–228.

Barcelona M.A.D. 2004. Let the rural folks do the talking. Focus group discussion as a tool for monitoring biodiversity and resource use in remote barangays of the Northern Sierra Madre Natural Park. Unpublished MA thesis, College of Mass Communication, University of the Philippines, Diliman, the Philippines.

Brashares J.S. and Sam M.K. 2005. How much is enough? Estimating the minimum sampling required for effective monitoring of African reserves. Biodivers. Conserv. 14: 2709–2722.

Collar N.J., Mallari N.A.D. and Tabaranza B.R.Jr. 1999. Threatened Birds of the Philippines. The Haribon Foundation/BirdLife International Red Data Book. Bookmark, Makati City, The Philippines.

Danida 2000. Towards 'Best' Practice in Biodiversity Conservation in Southern Africa. Royal Danish Ministry of Foreign Affairs, Copenhagen, Denmark.

Danielsen F., Balete D.S., Poulsen M.K., Enghoff M., Nozawa C.M. and Jensen A.E. 2000. A simple system for monitoring biodiversity in protected areas of a developing country. Biodivers. Conserv. 9: 1671–1705.

Danielsen F. and Treadaway C.G. 2004. Priority conservation areas for butterflies (Lepidoptera: Rhopalocera) in the Philippine islands. Anim. Conserv. 7: 79–92.

Danielsen F., Burgess N.D. and Balmford A. 2005. Monitoring matters: examining the potential of locally-based approaches. Biodivers. Conserv. 14: 2507–2542.

DENR 1992. National Integrated Protected Area System Act R. A. No. 7586 and Implementing Rules and Regulations DAO 25, Series of 1992. DENR, PAWB, Manila.

DENR 2000. Guidelines on the Implementation of the Biodiversity Monitoring System (BMS) in Protected Areas. DAO 13, Series of 2000. DENR, PAWB, Manila.

DENR 2001. Adoption of Prescribed Methods in Monitoring Biodiversity. DAO 6, Series of 2001. DENR, PAWB, Manila.

Fowler J. and Cohen L. 1988. Statistics for Ornithologists. BTO Guide No. 22. British Trust for Ornithology, Norfolk, UK.

Green R.E., Balmford A., Crane P.R., Mace G.M., Reynolds J.D. and Turner R.K. 2005. A framework for improved monitoring of biodiversity: Responses to the World Summit on Sustainable Development. Conserv. Biol. 19: 56–65.

Heaney L.R. and Mallari N.A.D. 2002. A preliminary analysis of current gaps in the protection of threatened Philippine terrestrial mammals. Sylvatrop. Techn. J. Phil. Ecos. Nat. Res. 10: 28–39.

Hockley N.J., Jones J.P.G., Andriahajaina F.B., Manica A., Ranambitsoa E.H. and Randriamboahary J.A. 2005. When should communities and conservationists monitor exploited resources? Biodivers. Conserv. 14: 2795–2806.

IUCN 2003. 2003 IUCN Red List of Threatened Species. www.redlist.org.

Kennedy R.S., Gonzales P.C., Dickinson E.C., Miranda H.C.Jr. and Fisher T.H. 2000. A guide to the Birds of the Philippines. Oxford University Press, Oxford, UK.

Loh J., Green R.E., Ricketts T., Lamoreux J., Jenkins M., Kapos V. and Randers J. 2005. The Living Planet Index: using species population time series to track trends in biodiversity. Philos. Trans. Roy. Soc. Lond. Ser. B 360: 289–295.

Mallari N.A.D., Tabaranza B.R.Jr. and Crosby M.J. 2001. Key Conservation Sites in the Philippines. Haribon Foundation, BirdLife International, DENR and Bookmark, Manila.

NORDECO and DENR. 1998a. Integrating Conservation and Development in Protected Area Management in Northern Sierra Madre Natural Park, The Philippines. DENR, Manila and NORDECO, Copenhagen.

NORDECO and DENR. 1998b. Integrating Conservation and Development in Protected Area Management in Bataan Natural Park, The Philippines. DENR, Manila and NORDECO, Copenhagen.

NORDECO and DENR. 1998c. Integrating Conservation and Development in Protected Area Management in Mt. Kitanglad Range Natural Park, The Philippines. DENR, Manila and NORDECO, Copenhagen.

NORDECO and DENR 2002. DENR Biodiversity Monitoring System Implementation Results from Eight Protected Areas January 1999–June 2001, The Philippines. DENR, Manila.

Obura D.O., Wells S., Church J. and Horrill C. 2002. Monitoring of fish and fish catches by local fishermen in Kenya and Tanzania. Mar. Freshwater Res. 53: 215–222.

Poulsen M.K. and Luanglath K. 2005. Projects come, projects go: Lessons from participatory monitoring in southern Laos. Biodivers. Conserv. 14: 2591–2610.

Roberts R.L., Donald P.F. and Fischer I.J. 2005. Wordbirds: Developing a web-based data collection system for the global monitoring of bird distribution and abundance. Biodivers. Conserv. 14: 2807–2820.

Robertson D.P. and Hull R.B. 2001. Beyond biology: toward a more public ecology for conservation. Conserv. Biol. 15: 970–979.

Sheil D. 2001. Conservation and biodiversity monitoring in the tropics: realities, priorities and distractions. Conserv. Biol. 15: 1179–1182.

Sheil D. and Lawrence A. 2004. Tropical biologists, local people and conservation: new opportunities for collaboration. Trend Ecol. Evol. 19: 634–638.

Thompson W.L., White G.C. and Gowan C. 1998. Monitoring Vertebrate Populations. Academic Press, London.

Topp-Jørgensen E., Poulsen M.K., Lund J.F. and Massao J.F. 2005. Community-based monitoring of natural resource use and forest quality in montane forests and miombo woodlands in Iringa District, Tanzania. Biodivers. Conserv. 14: 2653–2677.

Uychiaoco A.J., Arceo H.O., Green S.J., De la Cruz M.T., Gaite P.A. and Aliño P.M. 2005. Monitoring and evaluation of reef protected areas by local fishers in the Philippines: tightening the adaptive management cycle. Biodivers. Conserv. 14: 2775–2794.

Watson I. and Novelly P. 2004. Making the biodiversity monitoring system sustainable: Design issues for large-scale monitoring systems. Austral Ecol. 29: 16–30.

Yoccoz N.G., Nichols J.D. and Boulinier T. 2001. Monitoring of biological diversity in space and time. Trend Ecol. Evol. 16: 446–453.

APPENDIX XX

Danielsen, F., Burgess, N.D., Jensen, P.M. and Pirhofer-Walzl, K. 2010. Environmental monitoring: the scale and speed of implementation varies according to the degree of peoples involvement.
Journal of Applied Ecology 47: 1166–1168 (with cover page).

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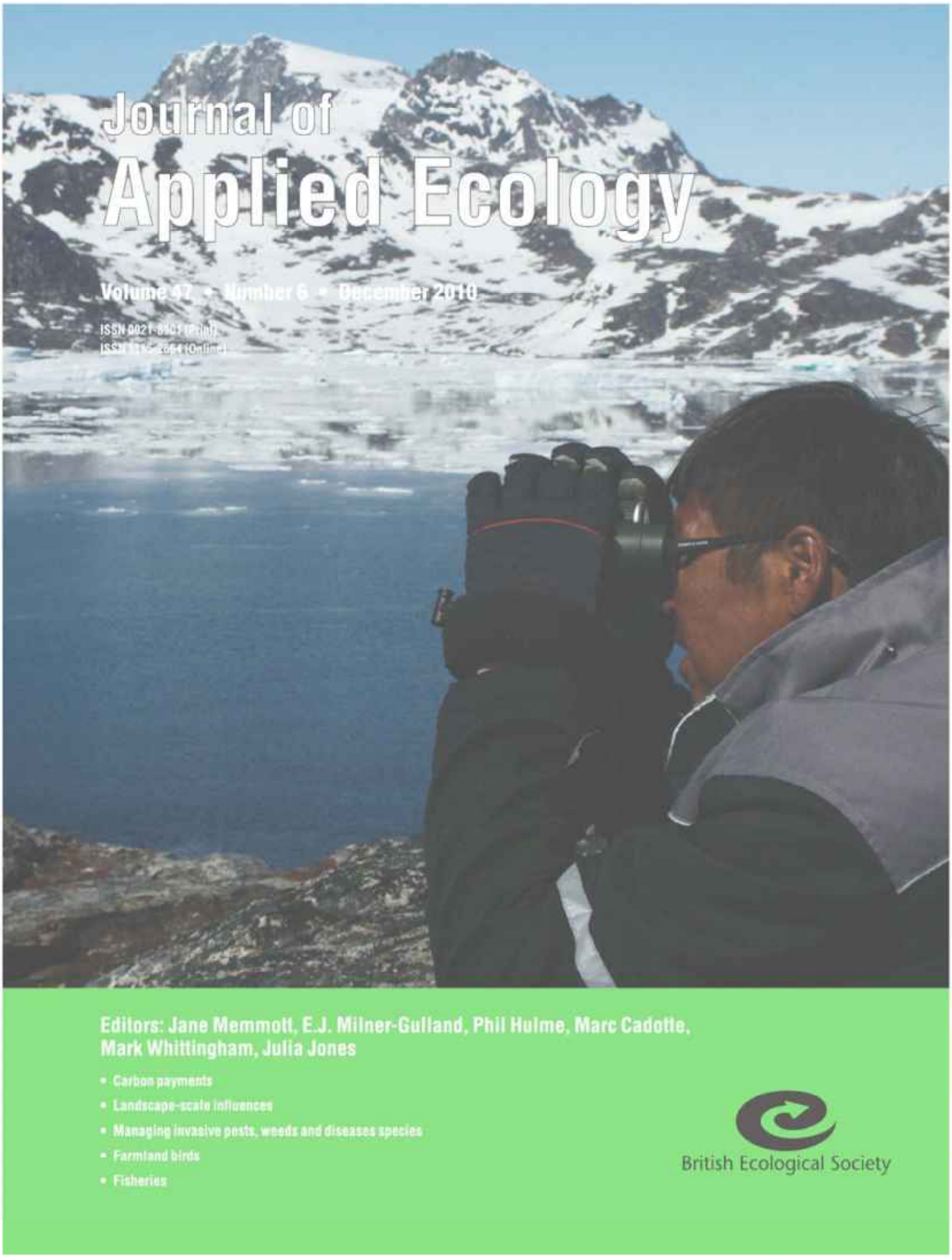

The Government of Greenland is pilot-testing the use of locally based monitoring of living resources as a tool for improving Arctic resource management. New findings by Finn Danielsen and his colleagues (see p. 1166) suggest that involving local stakeholders in environmental monitoring enhances management responses at local spatial scales, and increases the speed of decision-making to tackle environmental challenges at operational levels of resource management. Locally based monitoring may be particularly useful in those areas where the government's role in influencing land-use is minimal and village decision makers are in practice the day-to-day managers of natural resources and make most of the management decisions. Photo by Elmer Topp-Jørgensen.

Journal of Applied Ecology

British Ecological Society

Journal of Applied Ecology 2010, **47**, 1166–1168 doi: 10.1111/j.1365-2664.2010.01874.x

FORUM

Environmental monitoring: the scale and speed of implementation varies according to the degree of people's involvement

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Summary

1. Solutions to the global environmental crisis require scientific knowledge and responses spanning different spatial scales and levels of societal organization; yet understanding how to translate environmental knowledge into decision-making and action remains limited.

2. We examined 104 published environmental monitoring schemes to assess whether participation in data collection and analysis influences the speed and scale of decision-making and action.

3. Our results show that scientist-executed monitoring informs decisions within regions, nations and international conventions. However, decisions typically take 3–9 years to be implemented.

4. We also show that scientist-executed monitoring has little impact at the village scale, where many natural resource management decisions are made.

5. At the village scale, monitoring schemes that involve local people, and relate to resource utilization at the village level, are much more effective at influencing decisions; these decisions typically take 0–1 year to be implemented.

6. *Synthesis and applications.* Involving local stakeholders in monitoring enhances management responses at local spatial scales, and increases the speed of decision-making to tackle environmental challenges at operational levels of resource management.

Key-words: 2020 target, biodiversity monitoring, citizen science, climate change, decision-making, locally based monitoring, natural resource management, participatory monitoring, REDD, stakeholder participation

It is now clear that the world has failed to achieve the United Nations' 2010 target to stem biodiversity loss (Butchart *et al.* 2010; European Union 2010). Additionally, anthropogenic global changes continue to undermine the ecosystem services upon which society depends (United Nations 2005; CAFF 2010). Future attempts to reverse this multifaceted crisis need scientific information (Hobbs 2003) and responses spanning different spatial scales and levels of societal organization (United Nations 2005; Sandbrook *et al.* 2010), yet understanding how to translate environmental knowledge into decision-making and action is limited (Mooney & Mace 2009; Milner-Gulland *et al.* 2010).

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Case studies suggest that collaboration between scientists and local stakeholders in producing knowledge on the status of the natural resources can lead to favourable outcomes for the environment (Sheil & Lawrence 2004; Lawrence 2010), but quantitative analysis is lacking. Here we use meta-analysis techniques to explore if public participation in environmental monitoring influences the speed and spatial scale of decision-making and resulting action to address environmental challenges.

We first established a database of 104 publications on environmental monitoring schemes where the role of scientists and local stakeholders in the monitoring was described (see Appendix S1 and Table S1, Supporting information). We then identified who made decisions based on the results of the monitoring, and assessed the minimum time from the start of

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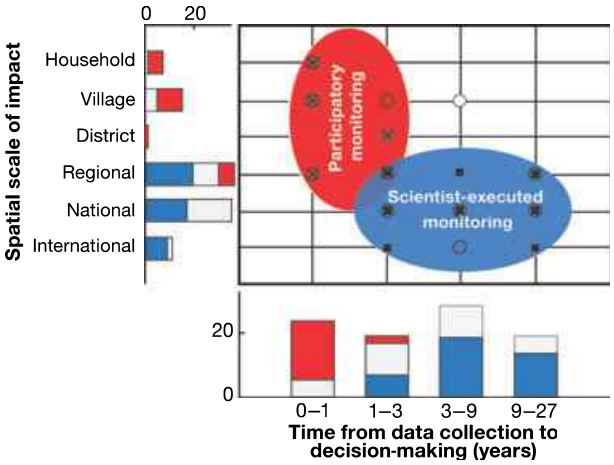

Fig. 1. Decision-making from environmental monitoring, based on data from published monitoring schemes 1989–2009 (n = 104). ■, scientist-executed monitoring schemes (n = 45); ○, monitoring schemes with local data collectors (n = 37); and ×, participatory monitoring schemes (n = 22). The circles comprise all the scientist-executed (blue) and all the participatory monitoring schemes (red). The bar chart indicates the number of scientist-executed monitoring schemes (blue bars), monitoring schemes with local data collectors (white bars) and participatory monitoring schemes (red bars) at each level of spatial scale and implementation time.

the data collection to the findings being used for decision-making.

The degree of involvement by local stakeholders in environmental monitoring profoundly influences the spatial scale and speed of decision-making based on the monitoring data (Fig. 1; Table S2). Scientist-executed monitoring informs decisions in regions (44%), nations (38%) and international conventions (18%) (n = 45 scientist-executed schemes). However, in many areas, particularly in the developing world, the government's role in influencing land-use is minimal and village decision makers are in practice the day-to-day managers of natural resources and make most of the management decisions (Getz *et al.* 1999). Scientist-executed monitoring has little impact at this scale (Fig. 1). Instead, the monitoring schemes that inform decision-making and resource utilization at the village level are those that engage people in the participatory collection, analysis and interpretation of the environmental data (Fig. 1). The greater the involvement by local people in monitoring activities the shorter time it takes from data collection to decision-making following monitoring ($P < 0{\cdot}001$; see Appendix S1, Fig. 1 and Table S2b). Two types of participatory monitoring are recognized; one where local people collect data but the analysis is done by someone else, and another where local people collect and analyse the data themselves. The most locally based and participatory of these two options leads to management decisions, which are typically taken at least three to nine times more quickly than scientist-executed monitoring, although they operate at much smaller spatial scales ($P < 0{\cdot}001$; see Appendix S1, Fig. 1 and Table S2a).

A limitation in our approach is that many environmental monitoring schemes are not published in the peer-reviewed literature. By using electronic databases for locating examples of monitoring schemes, we probably have disproportionally included schemes from large, well-funded programmes where academic publication has been a primary, or main, goal. We do not know if the spatial and temporal scale of decision-making in the published schemes is representative of the environment monitoring schemes that are being used in practice, but we believe that they represent the range of variation. Further studies aimed at providing more accurate assessments of environmental monitoring schemes could use questionnaires to natural resource managers and investigate those schemes they use. Another limitation is that management decisions might have gone unreported or might only have taken place beyond the period reported in the papers. Also, we don't know if the natural resource management decisions emanating from the monitoring are implemented successfully or not. We could have overcome uncertainties in data interpretation by validating and cross-checking our records with the authors of the papers on the 104 monitoring schemes in our sample. However, this could have introduced methodological differences between studies for which confirmation was available and studies which could not be validated. As the frequency of validation would be likely to vary across the type of monitoring, possible added accuracy would be associated with increased across-scheme bias. Overall, we consider the magnitude of our estimates and their relative proportions acceptable for the purposes of this paper, although figures from individual schemes are subject to uncertainty.

Our findings suggest that the type of monitoring undertaken in an area can have dramatic impacts on the solution chosen for different environmental challenges. By using scientists to undertake monitoring, there is a strong chance that decisions will only be taken at the large scale and will take years to implement. As such, this kind of monitoring is useful to influence national and international policy and to track the implementation of global conventions. At more operational scales of management, at the local level and involving people who face the daily consequences of environmental changes, scientist implemented monitoring generally has little impact. At these scales it is often more beneficial to involve local resource managers directly in the monitoring work; this allows them to assess trends in resources of value to them, and facilitates a rapid response in terms of decisions that directly impact environmental trends at the local scale.

Participation of community members in environmental monitoring may also have other benefits than aiding decision-making and management action (Danielsen, Burgess & Balmford 2005). For instance, even in scientist-led monitoring schemes (Janzen 2004), involvement of community members as paid staff in field-based inventories can help develop a change in attitude towards environmentally sustainable natural resource management among the local participants (Gardner 2010).

A consequence of our findings is that unless governments and non-governmental organizations involve local stakeholders, in many areas, environmental monitoring will tend to remain an isolated academic exercise that is primarily

undertaken for the benefit of national and international stakeholders. Involving the locally based stakeholders in monitoring will both enhance management responses across spatial scales, and improve the speed of decision-making to tackle current negative environmental trends at operational levels of resource management.

References

Butchart, S.H.M., Walpole, M., Collen, B., Strien, A.V., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M. *et al.* (2010) Global biodiversity: indicators of recent declines. *Science*, **328**, 1164–1168.

CAFF (2010) *Arctic Biodiversity Trends 2010 – Selected Indicators of Change*. CAFF International Secretariat, Akureyri, Iceland (available at http://www.arcticbiodiversity.is).

Danielsen, F., Burgess, N.D. & Balmford, A. (2005) Monitoring matters: examining the potential of locally-based approaches. *Biodiversity and Conservation*, **14**, 2507–2542. (available at http://www.monitoringmatters.org).

European Union (2010) *EU Council Conclusions on Biodiversity Post-2010*. http://www.europa-eu-un.org/articles/en/article_9571_en.htm. Accessed 22 April 2010.

Gardner, T. (2010) *Monitoring Forest Biodiversity. Improving Conservation through Ecologically Responsible Management*, pp. 291–311. Earthscan, London.

Getz, W.M., Fortmann, L., Cumming, D., du Toit, J., Hilty, J., Martin, R., Murphree, M., Owen-Smith, N. *et al.* (1999) Sustaining natural and human capital: villagers and scientists. *Science*, **283**, 1855–1856.

Hobbs, N.T. (2003) Challenges and opportunities in integrating ecological knowledge across scales. *Forest Ecology and Management*, **181**, 223–238.

Janzen, D.H. (2004) Setting up tropical biodiversity for conservation through non-damaging use: participation by parataxonomists. *Journal of Applied Ecology*, **41**, 181–187.

Lawrence, A. (2010) Introduction: learning from experiences of participatory biodiversity assessment. *Taking Stock of Nature. Participatory Biodiversity Assessment for Policy, Planning and Practice* (ed A. Lawrence), pp. 1–29. Cambridge University Press, Cambridge.

Milner-Gulland, E.J., Fisher, M., Browne, S., Redford, K.H., Spencer, M. & Sutherland, W.J. (2010) Do we need to develop a more relevant conservation literature? *Oryx*, **44**, 1–2.

Mooney, H. & Mace, G. (2009) Biodiversity policy challenges. *Science*, **325**, 1474.

Sandbrook, C., Nelson, F., Adams, W.M. & Agrawal, A. (2010) Carbon, forests and the REDD paradox. *Oryx*, **44**, 330–334.

Sheil, D. & Lawrence, A. (2004) Tropical biologists, local people and conservation: new opportunities for collaboration. *Trends in Ecology & Evolution*, **19**, 634–638.

United Nations (2005) *Millennium Ecosystem Assessment*. Island Press, Washington.

Received 25 February 2010; accepted 17 August 2010
Handling Editor: Paul Armsworth

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. The materials and methods, and the results of the statistical tests.

Table S1. Summary of the dataset of published environmental monitoring schemes.

Table S2. Decision-making from published environmental monitoring schemes.

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APPENDIX XXI

Gardner, T.A., Burgess, N.D., Aguilar-Amuchastegui, N., Barlow, J., Berenguer, E., Clements, T., **Danielsen, F.**, Ferreira, J., Foden, W., Kapos, V., Khan, S.M., Lees, A.C., Parry, L., Roman-Cuesta, R.M., Schmitt, C.B., Strange, N., Theilade, I., and Vieira, I.C.G. 2012.
A framework for integrating biodiversity concerns into national REDD+ programmes.
Biological Conservation 154: 61–71.

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Biological Conservation 154 (2012) 61–71

Contents lists available at SciVerse ScienceDirect

Biological Conservation

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Special Issue Article: REDD+ and conservation

A framework for integrating biodiversity concerns into national REDD+ programmes

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ARTICLE INFO

Article history:
Available online 20 December 2011

Keywords:
REDD+
UNFCCC
Biodiversity
Safeguards
Tropical forests
Conservation

ABSTRACT

The UNFCCC mechanism for Reducing Emissions from Deforestation and Degradation in developing countries (REDD+) represents an unprecedented opportunity for the conservation of forest biodiversity. Nevertheless, there are widespread concerns surrounding the possibility of negative environmental outcomes if biodiversity is not given adequate consideration throughout the REDD+ process. We propose a general framework for incorporating biodiversity concerns into national REDD+ programmes based on well-established ecological principles and experiences. First, we identify how biodiversity distribution and threat data, together with data on biodiversity responses to forest change and management, can be readily incorporated into the strategic planning process for REDD+ in order to identify priority areas and activities for investment that will deliver returns for both carbon and biodiversity. Second, we propose that assessments of changes in biodiversity following REDD+ implementation could be greatly facilitated by paralleling, where possible, the existing IPCC architecture for assessing carbon emissions. A three-tiered approach is proposed for biodiversity assessment, where lower tiers can provide a realistic starting point for countries with fewer data and lower technical capacities. Planning and assessment of biodiversity safeguards for REDD+ need not overburden an already encumbered UNFCCC process. Immediate progress is already possible for a large number of developing countries, and a gradual, phased approach to implementation would minimise risks and facilitate the protection of additional biodiversity benefits from REDD+ activities. Greater levels of coordination between the UNFCCC and CBD, as well as other agencies and stakeholder groups interested in forest conservation are needed if biodiversity safeguards are to be fully adopted and implemented.

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1. Introduction

One of the most significant developments arising from the 2010 16th Conference of the Parties (COP 16) of the United Nations Framework Convention on Climate Change (UNFCCC), was the adoption of a set of policy approaches and positive incentives to reduce greenhouse gas emissions through the conservation and management of forests in developing countries (the Cancun Agreements; Decision 1; Paragraphs 68–79 of COP 16, and associated annex). Commonly known as REDD+, this mechanism includes five sets of activities or interventions, namely; reducing emissions from deforestation, reducing emissions from forest degradation, conservation of (existing) forest carbon stocks, sustainable management of forests, and enhancement of

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doi:10.1016/j.biocon.2011.11.018

forest carbon stocks (e.g. through regeneration and planting in previously forest land). Taken together this set of recommendations represents a major and positive shift in the attention given to the potential role of forests in the developing world (non-Annex 1 countries, UNFCCC) in helping to stabilise the global climate, and offers the prospect of unprecedented levels of funding for forest conservation.

REDD+ also has the potential to deliver enormous benefits for biodiversity conservation because forests in the developing world harbour much of the world's terrestrial and freshwater biota, and are also threatened by ongoing forest clearance and degradation. As a result, REDD+ has generated significant attention in the conservation science community (e.g. Stickler et al., 2009; Harvey et al., 2010; Strassburg et al., 2009; Busch et al., 2011), as well as within the Convention on Biological Diversity (CBD) itself (CBD, 2011a). However, despite this considerable potential, concerns have been raised about possible negative environmental outcomes of REDD+ if key safeguards are not observed and integrated into the design and implementation of REDD+ activities (Ghazoul et al., 2010; CBD, 2011a; Epple et al., 2011; Pistorius et al., 2011). These concerns were formally recognised in the Cancun Agreements through the adoption of guidance and safeguards for policy approaches and positive incentives (Appendix 1 Decision 1/CP.16) which state that REDD+ activities should "*Be consistent with the objective of environmental integrity and take into account the multiple functions of forests and other ecosystems*" and, further "*That actions are consistent with the conservation of natural forests and biological diversity, ensuring that* [REDD+ activities] *are not used for the conversion of natural forests, but are instead used to incentivize the protection and conservation of natural forests and their ecosystem services, and to enhance other social and environmental benefits*".

Progress has also been made outside the UNFCCC process to develop more elaborate environmental standards and safeguards for organisations involved in advising on, verifying and funding the development of REDD+ activities. These include the Forest Carbon Partnership Facility's Strategic Environmental and Social Assessment Framework; the REDD+ Social and Environmental Standards of the Climate, Community and Biodiversity Alliance (CCBA) and CARE International (CCBA, 2008), and a growing set of guidance documents from the UN REDD programme (e.g. Epple et al., 2011), and independent research institutions (e.g. Pistorius et al., 2011; Pitman, 2011).

Environmental concerns surrounding REDD+ can be broadly divided into three, overlapping categories: ensuring that no further harm is done to natural forests, maintaining the long-term ecological integrity of forests, and capitalising on opportunities to secure net-positive impacts for biodiversity (CBD, 2010). The first set of concerns relates primarily to the risk of conversion of natural forests, the displacement (leakage) of deforestation and forest degradation activities to areas of lower carbon but high biodiversity value (including non-forest ecosystems such as savannahs), and the potential for afforestation of non-forest land (currently under negotiation ahead of COP 17), all as a direct or indirect result of REDD+ activities. The second set of concerns is focussed on ensuring the permanence of forest carbon stocks and emphasises the importance of considering the functional significance of biodiversity (Diaz et al., 2009; Thompson et al., 2009) and lessons from landscape ecology and the ecosystem approach (Gardner et al., 2009) as enabling conditions for maintaining ecological resilience in human-modified forest ecosystems. The third type of concern relates to the risk of failing to exploit significant economies of scale and deliver additional benefits for biodiversity if REDD+ activities are not designed strategically, and with due consideration of forest conservation and biodiversity targets and incentives outside the strict remit of the UNFCCC negotiations (Miles and Kapos, 2008).

In spite of their recognised importance, there is an urgent need for clear operational guidance on how the biodiversity safeguards adopted by the Cancun Agreements can be integrated into REDD+ activities (as well as voluntary carbon projects) in practice (Epple et al., 2011; Pitman, 2011). Both the UNFCCC and the CBD have made formal requests (through the Subsidiary Body for Scientific and Technical Advice; SBSTA, and COP 10 (Decision X/33 paragraph 9)) for advice on implementing biodiversity safeguards ahead of the UNFCCC COP 17 and CBD COP 11 in Durban (2011) and Hyderabad (2012) respectively. The main purpose of this paper is to help respond to these calls, and to provide some suggestions on a possible way forward.

The UNFCCC calls for the development of a "*system for providing information on how safeguards are being addressed and respected through the implementation of [REDD+] activities*" (Decision 1/CP.16 p71d). In addition the CBD has identified itself as having a key role in supporting the work of the UNFCCC, and in September 2011 made a submission to the UNFCCC regarding methodological guidance for developing such information systems (CBD, 2011b). Here we propose a general framework for incorporating the biodiversity concerns encompassed in the safeguards of the Cancun Agreements into the planning and assessment (used here to describe the post-implementation monitoring and assessment process in general) of REDD+ activities that is based on established ecological and conservation principles and experience (Fig. 1). By doing so we hope to demystify some of the challenges surrounding the integration of biodiversity concerns into REDD+ programmes, and demonstrate that tangible progress can already be made towards respecting safeguards using techniques and data that are already available. Whilst our proposal is focussed on national-level REDD+ programmes under the UNFCCC process the same basic framework can be readily applied to sub-national projects funded within the voluntary carbon market.

Our proposed framework is underpinned by two key arguments. First, safeguards can be most effectively addressed if explicit consideration is given to biodiversity concerns during all of the planning and design, implementation and assessment stages of the REDD+ process. Second, treatment of biodiversity can be made more cost-effective by linking any new planning and assessment work as closely as possible to the existing architecture for planning and assessing forest carbon conservation programs as laid out by the UNFCCC guidelines (see UNFCCC 2006, and also Meridian Institute, 2009a; GOFC-GOLD, 2010). We believe that the successful integration of biodiversity concerns within the REDD+ process could be facilitated by the adoption of a tiered approach that is partially analogous to the IPCC guidance on tiered-emissions reporting, in which lower tiers can provide a realistic starting point for countries with fewer data and lower technical capacities. The partial integration of concerns about both carbon and biodiversity within a common framework can help generate significant economies of scale in data collection and synthesis, while also facilitating communication and understanding of safeguards to a wider audience.

This paper is divided into two main sections. First, we outline the basic elements of our proposed framework with respect to REDD+ planning and assessment, and then use this framework to suggest approaches that could help to protect biodiversity, including integrating work with conservation programmes and funders outside the UNFCCC process. We finish by identifying priorities for future research that can facilitate future planning and action. Although this paper only deals with the integration of biodiversity concerns, we recognise that the successful implementation of REDD+ requires careful consideration of a wider range of social and economic factors to ensure that any investments are sustainable and result in socially just outcomes for local people (Ghazoul et al., 2010).

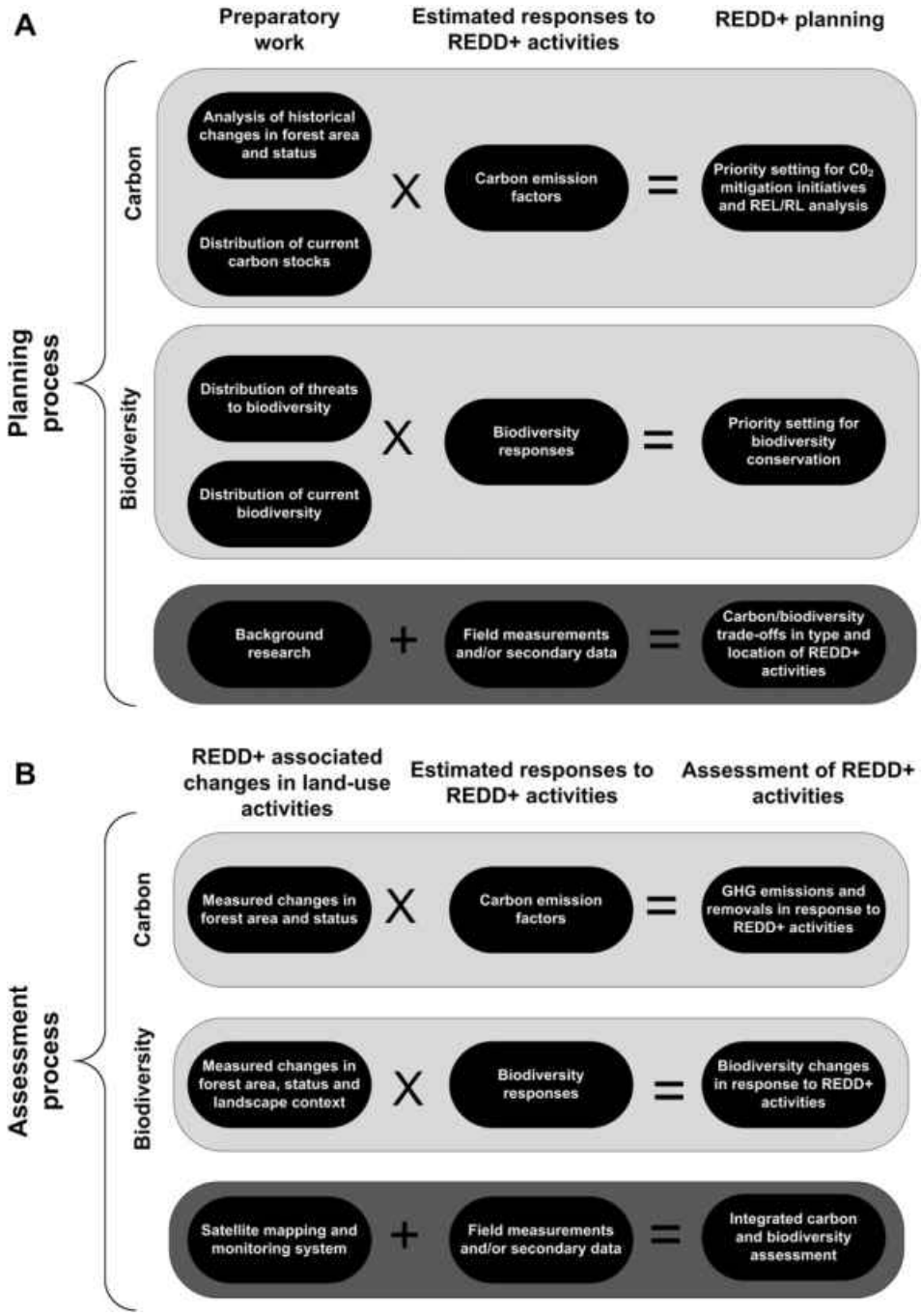

Fig. 1. A unifying framework for addressing concerns about both carbon and biodiversity into the planning (A) and assessment (B) processes of a national REDD+ programme. Biodiversity work maps closely onto the existing IPCC system for carbon, and makes use of many aspects of the same basic system for data collection and analysis. REL/RL refers to Reference Emissions Levels/Reference Levels. The level of specificity for all inputs (e.g. resolution of biodiversity distribution and response data, assessment of changes in landscape context) depends on the tier at which data are being collected and analysed (see Table 1). As well as being a mechanism for reporting and verification the assessment process should be viewed as an opportunity for learning – with outputs for both carbon and biodiversity contributing towards the ongoing revision of REDD+ planning and implementation.

2. Towards a framework for integrating biodiversity concerns into REDD+

2.1. Learning from carbon

A key step in the initial planning and design of national REDD+ programmes is to decide upon priority regions for investment in emissions reductions through forest conservation and management, and the types of REDD+ activities that should be implemented in such regions (Meridian Institute, 2011). To maximise emissions reductions this task is guided by an assessment of historical emissions from deforestation and degradation and information on the distribution of existing carbon stocks, in addition to considerations of the effectiveness, cost, social implications and the feasibility of REDD+ implementation.

In addition to such a strategic planning exercise, a carbon Monitoring Reporting and Verification (MRV) system is needed to assess and verify greenhouse gas (GHG) emissions reductions and removals from the atmosphere due to human activities. The national MRV systems that are currently being developed vary across

nations. Yet, in general terms, and by analogy with GHG emissions monitoring and reporting, a comprehensive national forest MRV system is likely to consist of two main data components: activity data to describe changes in forest cover, type and level of degradation and restoration, and 'emissions factors' which estimate likely changes in carbon stocks and emissions resulting from these activities. These data are then combined to calculate overall GHG emissions and removals as part of a National GHG Inventory (Meridian Institute, 2009a; GOFC-GOLD, 2010) (Fig. 1).

The specific requirements for REDD+ MRV systems have yet to be decided. However, the IPCC has defined a tiered approach to carbon emissions assessments in its Guidelines, with different tiers relating to differences in data requirements and analytical complexity (IPCC, 2006; Table 1). In the IPCC system Tier 1 employs default emissions factors (biomass estimates from different ecoregions) from the IPCC Guidelines (IPCC, 2006), Tier 2 includes country-level emission factors and a more detailed assessment of forest strata as well as explicit consideration of data uncertainties, and Tier 3 uses actual inventory data and repeated measurements of forest plots by national scientists and local people to directly measure and model changes in carbon stocks and individual pools. The tiered approach to assessment and monitoring enables countries to assess and report on emissions even when national data and capacities are limited, and makes clear how improvements can be achieved. It provides a clear structure for promoting transparency, consistency and accuracy.

We propose that biodiversity considerations can be readily incorporated into national REDD+ programs using a similar logic and framework to cover both planning and assessment (Figs. 1 and 2). Moreover, we argue that some level of integration is essential if biodiversity considerations are to be viable within REDD+ and neither overburden national capacity, nor become ignored because they are too costly to implement. Fig. 1 illustrates the three sets of inputs for planning and assessment of both carbon and biodiversity aspects of REDD+, namely; preparatory "status" data (analyses of historical changes in forest area and condition, distribution of existing carbon stocks and the distribution of biodiversity and biodiversity threats), activity (land-use) data, and response factors (emissions factors or biodiversity disturbance-responses). These inputs, together with a combined satellite and forest plot–based monitoring system can deliver integrated guidance on spatial land-use planning (i.e. which REDD+ activities to implement and where) and performance assessments (GHG emission assessment and estimates of change in the status of forest biodiversity). In an analogous way to carbon MRV, it is possible to identify different tiers of data requirement and analytical complexity for biodiversity assessments (Table 1). The next two sections discuss in more detail ways in which biodiversity concerns can be incorporated into REDD+ planning and assessment.

2.2. Incorporating biodiversity concerns into strategic REDD+ planning

Under the Cancun Agreements, countries wishing to enter the REDD+ mechanism need to undertake a thorough situation analysis and develop a national REDD+ action plan (i.e. accounting for national circumstances within the UNFCCC framework), a national reference level analysis and a national forest monitoring system. Tens of tropical developing countries are currently undertaking such REDD+ readiness activities, the majority of which are funded by one or more international programmes (including the Norwegian Climate and Forest Initiative programme of bilateral funding, which is also the main financier of the global UN-REDD programme, and the World Bank's Forest Carbon Partnership Fund and Forest Investment Programme). As noted above, key tasks within this work include deciding on priority regions for investment, and the types of REDD+ activities that should be implemented in such regions. Consideration of biodiversity can be incorporated into both sets of decisions using information on the spatial distribution of biodiversity and its threats, as well as known responses of species (or species group) to different forms of forest disturbance and management.

2.2.1. Spatial mapping of trade-offs and synergies between carbon and biodiversity

Reference levels provide a benchmark for estimating emissions reductions from REDD+ implementation in a given geographic area, and are developed by taking into account historical emissions (deforestation and degradation) and emissions reductions (sustainable forest management and enhancement of forest stocks) (Meridian Institute, 2011). By estimating the spatial distribution of threats facing forest ecosystems the reference level analysis, together with information on the distribution of existing carbon stocks and the effectiveness of different possible REDD+ activities helps guide coarse-scale priorities for investments in forest conservation (Fig. 1a, and see Busch et al., 2011 for a similar global-scale analysis). However, biodiversity poses a particular challenge for land-use planning and management because the composition of species and habitat types can vary greatly from place to place. Spatial data on the distribution of biodiversity, its threats, and/or proxies of these are therefore vital in helping to identify priorities for conservation investments that can be compared against spatial priorities for carbon investment (whilst also considering other social, economic and political factors).

Spatial carbon-biodiversity overlay analyses (Fig. 1a) can be conducted at various scales (where possible incorporating cost data as well) to identify either carbon–neutral solutions that offer varying benefits for biodiversity, or high return-on-investment opportunities where relatively minor adjustments to carbon objectives can deliver disproportionate benefits for biodiversity (Venter et al., 2009). Analyses can range from a very simple visual comparison of lookup tables of the ecological distinctiveness of different forest types to spatially explicit optimisation modelling within GIS environments (Wilson et al., 2010). Irrespective of the analytical approach used the key feature is the existence of comparable carbon and biodiversity information and its use to make more informed choices within national REDD+ programmes.

For example, one spatial overlay analysis of carbon and biodiversity using currently available global data (5-degree data on carbon stocks, and vector data on birds, mammals and amphibians, weighted by threat status) together with opportunity cost data has been prepared for Madagascar, to demonstrate cost-efficient approaches to bundling payments at the national scale (Wendland et al., 2010). Further work of this type for other countries (including DR Congo, Indonesia, and Tanzania) is underway at UNEP-WCMC with support of the UN-REDD programme. Here, we present an example map for Tanzania showing how carbon and biodiversity concerns can be effectively illustrated on the same map, potentially identifying regions where the conservation of forest carbon stocks would also maximise returns for the conservation of mammals (see Fig. 3) (Khan, 2011).

Spatial analyses such as these should ideally employ the best biodiversity and threat data that are available for that country, without embarking on costly new field surveys. Where country specific spatial data on biodiversity are not available, standardised global data sets can be employed, including maps of globally consistent biogeographical regions (e.g. WWF and TNC's Ecoregions), areas of particular importance for conservation identified at different scales (e.g. Endemic Bird Areas, Biodiversity Hotspots, Global 200 ecoregions (large areas) and Important Bird Areas, Alliance for Zero Extinction Sites and Key Biodiversity Areas (smaller areas), Schmitt, 2011), and systematically mapped species distribution data (e.g. NatureServe, IUCN Red List and species group-specific

Table 1
Example of a tiered approach to integrating biodiversity concerns into assessment (MRV) frameworks for national REDD+ programmes. This builds upon, and uses, data collected in the REDD+ planning stage. It also mirrors the tiered approach for MRV of carbon established by the IPCC. Higher level tiers will in general involve increasing levels of accuracy but also greater complexity and requirement for technical expertise. Implementation could be achieved by a variety of agencies and has clear linkages to the work programmes and goals of both the UNFCCC and CBD.

Tier of assessment	Description of carbon elements at analogous tiers as defined by IPCC protocol	Corresponding approach for biodiversity assessment	Strengths and weaknesses	Suggestions for appropriate lead agencies
1. Derived using globally available data on changes in the area and type of forest and relevant biodiversity attributes	IPCC default values obtained from the IPCC Emission Factor Data Base (i.e., biomass in different forest ecoregions). Biomass estimates provide limited resolution of how forest biomass varies sub-nationally and have a large error range. Uses simplified assumptions (including instantaneous losses) to calculate emissions	Employs best available biodiversity data coupled with rates of change in forest area within and between regions of known ecological distinctiveness. Relies upon coarse-scale estimates of forest type and levels of disturbance. Assumes instantaneous changes in biodiversity values when moving between land-use classes, and discounts any possible landscape-scale processes	*Strengths*: Measures of forest loss and change in area can be readily calculated from the forest benchmark map required to establish carbon baselines for REDD+. Comparison with crude spatial proxies of biodiversity uniqueness, derived from globally available databases is then a relatively trivial process (e.g. WWFs Ecoregions database, Endemic Bird Areas, Biodiversity Hotspots, Key Biodiversity Areas/Important Birds Areas databases or species data from Nature Serve, IUCN-SSC, Herpnet, Antweb etc.) *Weaknesses*: Limited to interpretation of changes in forest area, and does not capture estimates of biodiversity change in areas of forest that stay as forest (either through degradation or restoration). Relies on proxy measurements of biodiversity value rather than validated data	Joint assessment by national REDD+ assessment units in partnership with government CBD focal points, and with technical assistance from biodiversity specialists in NGOs and research organisations
2. Derived using nationally generated remote sensing data to produce refined assessment of changes in biodiversity value and ecological condition across forest types and landscapes	Static forest biomass information which uses country-specific data and a delineation of more detailed forest strata (types and levels of degradation). Uses disturbance matrices that model carbon retention, transfers and releases among pools (instead of assuming instantaneous losses).	Uses biome and national scale biodiversity response and spatial data, coupled with rates of change in forest area, condition, and landscape-scale fragmentation. Does not involve any collection of new biodiversity data. Can employ a range of remote-sensing techniques to estimate changes in forest degradation, fragmentation and regeneration processes at local and landscape scales	*Strengths*: National data has national and even local ownership and is thus more likely to reflect national conservation priorities. Can capitalise on global biodiversity data compilation efforts and improve them through national expertise. Provides more detailed proxies of changes in forest biodiversity beyond simple changes in forest area and type, including estimates of degradation status, and forest fragmentation. *Weaknesses*: Relies on proxy measurements of biodiversity value that are not validated with ground data. Good, recent national level spatial data on biodiversity may be unavailable, or limited to certain species groups	Joint assessment by national REDD+ assessment units in partnership with government CBD focal points, and with technical assistance from biodiversity specialists government, NGOs and research organisations
3. Derived using data collected from ground-based forest and biodiversity surveys	Employs actual inventories with repeated measures of permanent plots to directly measure changes in forest biomass. Uses carbon models parameterised with plot data. Employs modelled estimates of transfers and releases among pools to more accurately reflect how carbon emissions are realised over time. In many countries, Tier 3 level forest biomass data can in practice only be compiled across large	Uses nationally derived field data on biodiversity, deforestation, degradation and fragmentation. Incorporates direct monitoring of biodiversity responses to REDD+ activities. Monitoring work is ideally stratified across land-use classes and areas exhibiting greatest changes (i.e. deforestation and forest degradation, or changes in forest management). Field data are ideally calibrated against	*Strengths*: Links biodiversity data directly to REDD+ activities and forest management, and is the only tier that allows the development of an improved understanding of forest degradation and the ecological resilience of human-modified forest landscapes. Can integrate closely with the field surveys required under tier 3 MRV for carbon. Provides information on threats to	National forest inventory teams from relevant government departments working with a joint REDD+/CBD steering committee. Tier 3 assessment of biodiversity safeguards offers significant potential for involvement (and co-funding) by the research community. Depending on the type of REDD+ activity and location, biodiversity monitoring could also be conducted by forestry

(*continued on next page*)

Table 1 (*continued*)

Tier of assessment	Description of carbon elements at analogous tiers as defined by IPCC protocol	Corresponding approach for biodiversity assessment	Strengths and weaknesses	Suggestions for appropriate lead agencies
	areas if local communities and organisations are involved in the collection of field data (see www.ciga.unam.mx/redd/events.php)	remote-sensing information allowing results of monitoring to feedback into an improved understanding and classification of the implications of different REDD+ activities for biodiversity. Should also include monitoring of local scale threatening processes that are likely to impact biodiversity	biodiversity and potential solutions. Can be linked directly to threat reduction and forest decision-making if involving community members in collecting and interpreting data *Weaknesses*: If carried out fully it requires a significant investment in the compilation of national databases, and in particular the collection and analysis of new field data	concessionaires and local communities, including indigenous people using participatory monitoring approaches. Technical oversight by a national steering committee is highly desirable to ensure data meet minimum standards of rigour and comparability

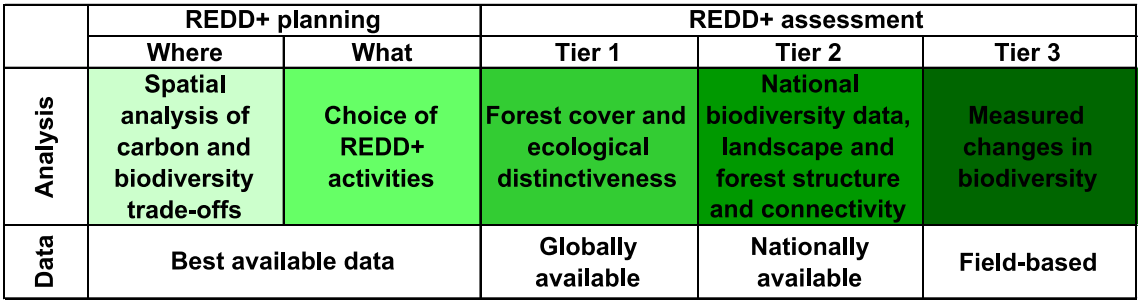

Fig. 2. Summary of ways in which concerns related to biodiversity safeguards can be incorporated into REDD+ planning and assessment. The strategic planning stage determines where REDD+ investments will be made and for which activities. The assessment process occurs at an operational level in areas that have received REDD+ investments; it can be implemented through different tiers of data requirement and complexity (see also Table 1). Assessment tiers relate broadly to the scale at which data are collected and summarised (globally, nationally and locally) but also include considerations of analytical complexity and uncertainty. Applying the framework outlined in this paper during the planning stage has the potential to deliver significant and cost-effective benefits for biodiversity, while assessment work is essential for verifying that plans have been appropriately implemented, and to provide much needed new information for the refinement of future planning processes.

geographic databases such as Herpnet and Antweb). In some parts of the world, region-wide collaborative efforts are emerging to document information on the distribution and threat status of certain species groups, such as the ASEAN Biodiversity Information Sharing Service (http://bim.aseanbiodiversity.org/biss/). To aid analyses of such data, a number of free online tools are being developed to allow coarse scale analyses that integrate information on biodiversity, carbon and costs to help identify high priorities for REDD+ investments (e.g. InVest – http://www.naturalcapitalproject.org/InVEST.html, and Marxan – http://www.uq.edu.au/marxan/). A comprehensive review of currently available biodiversity and forest degradation data, and observational systems has been compiled by the Group on Earth Observation Biodiversity Observation Network (GEO BON, 2011).

2.2.2. Considering the impacts of different REDD+ activities on biodiversity

For both planning and assessment it is important to understand how different REDD+ activities may impact (positively or negatively) forest biodiversity, and their consequences for the long-term integrity and conservation of forest ecosystems (Fig. 1). The best available data should be used to assess the biodiversity impacts (positive or negative) of implementing different combinations of REDD+ activities. Many studies have compared changes in biodiversity following different types of tropical forest modification or conservation (Gardner et al., 2009), with an increasing number of quantitative synthesis becoming available. Gibson et al. (2011) recently presented a global meta-analysis of studies across the tropics, while Sodhi et al. (2008) gave a similar summary focussed on the South East Asian biota. Other reports have focussed on biodiversity responses to specific types of land-use change, such as natural regeneration of tropical secondary forests (Dent and Joseph Wright, 2009), agroforestry (Beukema et al., 2007) and forest restoration (Rey Benayas et al., 2009), as well as region-specific syntheses on topics such as the effects of logging, fragmentation and fire on Amazonian birds (Barlow et al., 2006). Assessments of biodiversity responses to land-use change are also available for specific taxonomic groups, such as tropical forest dung beetles (Nichols et al., 2007). Finally, large-scale multi-taxa field surveys can often provide valuable information on the likely consequences of particular REDD+ activities for regional biodiversity; examples include the assessment by Barlow et al. (2007) on the biodiversity consequences of conversion of primary forest to secondary and plantation forests in the eastern Amazon, and work by Berry et al. (2010) on biodiversity responses to regeneration of logged forests in Borneo.

As our understanding of tropical forest biodiversity improves, estimates of the biodiversity consequences of specific forest conservation or restoration activities can be complemented by information on changes in the wider landscape context. Landscape-scale characteristics, such as total forest cover, levels of fragmentation and historical disturbances can have a major impact on local biodiversity and the ecological resilience of modified landscapes (Gardner et al., 2009; Pardini et al., 2010), and therefore need to be considered when prioritising and assessing REDD+ investments. Consideration is also needed for aquatic habitats that

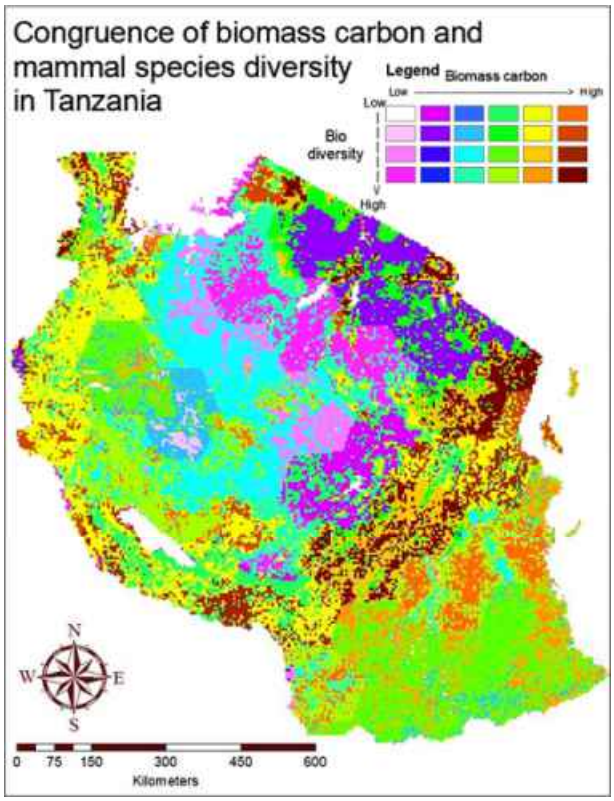

Fig. 3. Example national scale map for Tanzania displaying congruence values between carbon and biodiversity at the scale of a 5 km grid and across all vegetation types. Map generated using freely available landcover data from MODIS, mammal data from the freely available African mammal databank (African Mammals Databank (AMD) and African carbon data provided by UNEP-WCMC, based on multiple sources (Khan, 2011). This kind of simple overlay map can help in identifying those areas of both high opportunity (strong positive correlation in carbon and biodiversity values) and risk (low in carbon but high in biodiversity) in the REDD+ planning process.

can be seriously degraded through erosion and unsustainable forest land-uses.

Prioritising REDD+ investments should ideally consider data on both the spatial distribution of biodiversity and estimates of species responses to different forms of forest degradation and land-use change. Such analyses can help to identify the risks to biodiversity (and hence to the permanence of carbon stocks) from poorly designed REDD+ investments, as well as the 'low-hanging fruits' – where marginal adjustments to carbon-based priorities may deliver significant benefits for biodiversity conservation. Although they did not include carbon data, Wilson et al. (2010) provide an example of this approach, combining existing spatial data on 1086 mammals from the Asian Mammal Databank with expert- and literature-derived estimates of mammal sensitivity to different land-use classes to identify optimal zoning strategies for forest conservation in Kalimantan. Ultimately, such strategic planning exercises should also take into account threats to biodiversity that are currently beyond the remit of REDD+ activities, such as impacts from over-hunting and unsustainable extraction of non-timber forest products (Putz and Redford, 2009).

2.3. A tiered approach to assessing biodiversity change in REDD+ programs

We suggest that work to assess biodiversity concerns in REDD+ programmes should ideally perform two functions: provide transparency regarding the attainment of minimum standards (e.g. ensuring that REDD+ activities do not result in harm to biodiversity), and provide a learning mechanism for the refinement of future REDD+ investments. Table 1 describes in detail a possible three-tiered approach to assessing biodiversity concerns for the REDD+ assessment process, and illustrates the kinds of biodiversity indicators and measurements that could be employed for each tier, together with suggestions for lead agencies with relevant capacities. Much of the same biodiversity information can be used to inform both the planning and assessment processes. This combination of approaches mirrors in part the three-tiered IPCC scheme for assessing GHG emissions. Different tiers are distinguished largely by the scale at which biodiversity data are derived (global, national or project) and by a gradient of data quality, from coarse scale proxies of forest type, through remote-sensing derived indices of landscape structure and forest condition to field-derived biodiversity data (Fig. 2).

In our proposed Tier 1 approach coarse-scale and often readily available data are employed to track changes in forest type and area, and coupled with globally available biodiversity distribution and response data (as used during the planning stage, see Section 2.2). This assessment is focussed on highlighting possible threats to biodiversity as a consequence of REDD+ activities (e.g. an increase in the clearance or degradation of rare forest types that are low in carbon but ecologically distinct – a headline concern of the environmental safeguards in the Cancun Agreements).

The proposed Tier 2 approach provides an assessment of remote-sensing derived indicators of landscape structure (e.g. fragmentation indices such as average area of forest patches and total forest edge) and forest structural degradation (satellite-based indicators of logging scars and forest fires) (see Gardner, 2010; FAO, 2011; Herold et al., in press for a detailed review). Current IPCC guidelines lack consideration of forest fragmentation processes, landscape connectivity and resilience, yet these factors are of critical importance for biodiversity conservation and the maintenance of ecological resilience in human-modified landscapes (Gardner et al., 2009; Pardini et al., 2010). In addition to incorporating these indicators of forest condition, Tier 2 assessments should replace Tier 1 global datasets on biodiversity distribution and disturbance responses with national-level information, as well as give consideration to questions of data uncertainty.

The proposed Tier 3 differs from the others by including the collection of new biodiversity data. We believe it is unfeasible to suggest that biodiversity monitoring programmes are conducted at all (or even the majority of) REDD+ sites, or in a large number of sample sites within each forest type across a nation, yet the collection of data at a sub-sample of sites is important for validating indicators based on remote sensing data. The selection of sites and methods for on-the-ground biodiversity monitoring needs to proceed with considerable care because if it is not designed and implemented appropriately, biodiversity monitoring can be both a distraction and a waste of precious resources (Gardner, 2010), and risks overburdening the limited capacity available to support most REDD+ programmes. The sub-sample of sites selected for biodiversity monitoring should be targeted towards areas of forest that are undergoing the greatest changes (whether through clearance, degradation or restoration) so that monitoring data can help improve estimates of biodiversity responses to REDD+ activities. Stratification of sampling work can be guided by mapping and landscape analyses proposed at Tier 2. Care is needed in selecting appropriate monitoring teams, biodiversity and forest structure indicators and sampling sites (including reference sites; see Gardner, 2010; Pitman, 2011 for more detailed guidance on biodiversity monitoring, and Danielsen et al., 2000 for an example of a simple community-led monitoring scheme). Finally, it is possible that the most cost-effective way in which on-the-ground biodiversity monitoring can be achieved in many countries is by integrating the collection

of biodiversity data with the collection of carbon stock data from the same set of forest monitoring plots that are required under Tier 3 of the IPCC system (Teobaldelli et al., 2010), and ensuring the effective involvement of local people (Danielsen et al., 2011). If designed appropriately (i.e. stratified towards areas of greatest forest change), pre-existing National Forest Inventory plots may be suitable for this task.

3. Implementation aspects

Implementing robust biodiversity safeguards ultimately depends upon carrying out specific actions throughout the REDD+ planning and implementation process, including making choices about the type and location of REDD+ activities, and options for linking biodiversity concerns within ongoing carbon assessment work (Moss and Nussbaum, 2011). In addition, it may be necessary to consider additional management interventions (beyond exclusively carbon-focussed activities and national environmental legalisation that is already in place) in order to ensure the long-term conservation of biodiversity.

3.1. Assessing costs and benefits of integrating biodiversity concerns into REDD+ programmes

Commonly cited barriers to the implementation of biodiversity concerns in REDD+ are high cost and limited access to technical expertise. The fact that our proposed framework mirrors the existing IPCC system for carbon assessments significantly reduces these barriers, while the tiered approach to assessment allows some progress to be made in all tropical countries, regardless of their current capacity and data availability. Nevertheless, some costs and constraints will remain, and these may be significant for many developing countries.

Including biodiversity considerations through either Tier 1 or Tier 2 level assessments (Table 1) would often add only a fraction to the costs of the overall REDD+ MRV system, as the major additional requirements are in the systematic compilation of secondary data on biodiversity and the analyses of these data alongside existing forest cover and carbon measurements. The major costs of incorporating biodiversity concerns into national REDD+ programmes come from strategic adjustments to the REDD+ planning process (Figs. 1a and 3, and see Section 2.2), and Tier 3 level assessment where new field data are required to refine and report on changes in forest condition, integrity and biodiversity trends. These costs vary enormously depending on several inter-related factors. For the planning processes this includes the opportunity and management costs that are likely to come from any adjustments to the spatial priorities of REDD+ programmes that are concerned exclusively with carbon (e.g. Fisher et al., 2011), while for the assessment processes it includes consideration of whether monitoring work depends exclusively on scientists or involves/is led by local communities (Danielsen et al., 2011), the choice of species or indicator groups (Gardner et al., 2008), the design of the surveys (Garden et al., 2007) and whether biodiversity sampling can be included as part of existing or planned forest carbon plots (Teobaldelli et al., 2010). Finally, an additional cost in implementing biodiversity safeguards for REDD+ is likely to come from opportunity and management costs that are incurred during implementation if additional (i.e. non-carbon focussed) interventions are necessary (e.g. regulation of hunting and unsustainable timber harvesting).

A more comprehensive assessment of the costs of planning, implementing and assessing biodiversity safeguards in REDD+ programmes is urgently needed, including recognition of the significant economic benefits that are provided by the protection of biodiversity itself (TEEB, 2010). It is also important to identify the conservation benefits that may come from additional investments in biodiversity related work (whether in planning, implementation or assessment). Benefits are perhaps most clearly evident when analysing trade-offs in the spatial planning process. Indeed, one of the most powerful arguments for climate-biodiversity co-financing initiatives (see below) is the observation that the trade-off curve between carbon and biodiversity values is non-linear, such that significant improvements (as well as cost-savings) in biodiversity returns may be possible to achieve while incurring only relatively small carbon penalties (Venter et al., 2009).

A more systematic assessment of both the carbon and biodiversity consequences of different REDD+ activities in different places around the world would help further clarify the potential for cost-effective investments in implementing biodiversity safeguards. These opportunities may not necessarily be focussed on avoided deforestation. For example recent work demonstrating the rapid recovery of both carbon stocks and biodiversity through enrichment planting and rehabilitation of degraded forests (Edwards et al., 2010; Ansell et al., 2011; Sasaki et al., 2011) suggests that this relatively low-cost activity could provide substantial multiple benefits for many areas of the tropics where forests are heavily degraded. Another example is in passive forest restoration which can be much cheaper than active reforestation but may, depending on the intensity of past disturbance regimes, permit a significant recovery of both carbon and biodiversity (Holl and Aide, 2011). If made readily available, Tier 3 biodiversity assessments would provide an invaluable source of data to improve our understanding of different REDD+ options.

Within the context of international agreements, the primary responsibility for the conservation of forest biodiversity lies, not with the UNFCCC, but with the CBD. The recently agreed Aichi targets of the CBD, developed at the COP 10 meeting in Japan in 2010, lay out a series of targets within a strategic plan for the period to 2020 that match almost perfectly with the aspirations of the REDD+ mechanism. This includes specific targets to halve deforestation and reduce degradation and fragmentation (Target 5), manage all forests sustainably (Target 7), effectively conserve at least 17% of all terrestrial areas (Target 11), and restore at least 15% of degraded ecosystems to enhance both biodiversity and carbon (Target 15) (http://www.cbd.int/sp/targets/). However, irrespective of how responsibility is apportioned, biodiversity remains at the interface between multiple international and national agendas. Coordination between the Conventions, as well as amongst national level agencies and non-governmental organisations, will therefore be an important component of helping individual nations to maintain biodiversity through the conservation and responsible management of tropical forests (Pistorius et al., 2011).

We foresee considerable scope for progress through taking integrated action. For example, a lot of work relevant to our proposed approach has already been conducted at the national level as part of existing CBD commitments, including the development of National Biodiversity Strategy and Action Plan reports, and national gap analysis for the CBD Program of Work on Protected Areas (CBD, 2011a). Moreover, the CBD Aichi Target 17 commits countries to develop and start implementing an updated biodiversity strategy and action plan by 2015. Integration of these programmes of work with REDD+ programmes would achieve enormous cost savings, as well as streamline the technical assessments of both Conventions. Beyond the CBD, considerable synergies can be found with other organisations at both global (e.g. International Union for the Conservation of Nature, International Tropical Timber Organisation, major conservation organisations) and local scales (individual bilateral funding arrangements for sustainable forest conservation projects). In all these cases, strategic partnerships that link biodiversity policies with carbon emissions mitigation

policies such as REDD+ may reveal major cost-sharing opportunities for both areas, help ensure the long-term ecological integrity of carbon stocks, and aid in alleviating the chronic inadequacy of conservation budgets (Ring et al., 2010; Scharlemann et al., 2010). Further work is needed on the most appropriate mechanisms and scales at which climate-biodiversity strategic partnerships could work, with options including global funds (perhaps linked to the World Bank or Global Environment Facility) that can provide strategic top-ups to REDD+ funding to enable more detailed biodiversity safeguard components, and a case-by-case combination of bilateral and voluntary arrangements (Peterson et al., 2011).

3.2. A phased approach to integrating biodiversity concerns into REDD+

The UNFCCC process has recommended a phased approach to REDD+ implementation (see Paragraph 73 of Decision 1/CP.16, and Meridian Institute, 2009b) beginning with readiness planning, policy development and capacity building, followed by implementation of national strategies and results-orientated demonstration activities, and evolving into a full programme of results-orientated activities that should be fully measured, reported and verified. This framework has appeal as it promotes engagement by countries with weak capacity and low levels of resources, while encouraging a gradual increase in commitment over time.

The incorporation of biodiversity safeguards and concerns into REDD+ is still being negotiated, and approaches to implementation are likely to be left to the discretion of individual countries. Nevertheless, it is logical that a comparable phased system could be adopted for the integration of biodiversity concerns into the overall REDD+ process. Similar to the case for carbon, it may be appropriate that only planning aspects are considered within a REDD+ start-up phase. Even crude spatial overlay analyses and look-up tables with rough estimates of the carbon and biodiversity impacts of alternative REDD+ activities could help greatly to identify ways of enhancing biodiversity safeguards. Subsequent phases could then employ different tiers of biodiversity assessment, from coarse-scale monitoring of changes in the cover of different forest types and indicators of fragmentation and canopy disturbance to fully developed validation monitoring of biodiversity (Table 1 and Fig. 2).

Requirements for more detailed consideration of biodiversity could also be linked to differences in the levels and types of threat facing forest ecosystems. For example, in countries, regions or landscapes where forests are threatened by rampant clear-felling, priority needs to be given to measuring changes in the area and type of forest being lost (and on-the ground biodiversity monitoring would add little information). By contrast, in more consolidated and fragmented landscapes remaining areas of forest may be threatened by a multitude of interacting stressors, including logging, fire and over-harvesting of wildlife and non-timber forest products – thereby requiring a higher tier of assessment, and introducing greater need for ground-truthed data to interpret changes.

The tiers presented in our framework ultimately relate to varying levels of assurance that biodiversity safeguards are being addressed and respected (Fig. 2). The different tiers also serve complementary functions, and should be viewed as part of a nested system where Tier 3 monitoring is most effective if assessments at Tier 1 and 2 are already in place. Tiers 1 and 2 serve primarily as an audit function for reporting against minimum standards for implementing biodiversity safeguards, whilst Tier 3 helps guide local decision-making on forest management (at the scale of the individual forest area) and at the same time contributes to refining our understanding of coarse-scale proxies of biodiversity and helps guide future national strategic planning processes. The UNFCCC process is unlikely to formalise a multi-tiered approach to the assessment of biodiversity safeguards within REDD+ (although Tier 1 assessment would go a long way towards helping minimise risks). As a consequence movement towards higher level tiers will require increased investment from outside the UNFCCC process (e.g. through national biodiversity programmes, and donor funding).

4. Research priorities

Although our proposed framework rests on the argument that considerable progress can be made towards accounting for biodiversity safeguards in REDD+ using existing data and approaches, there are clearly many areas where improvements and new information and understanding is needed. Efforts to integrate biodiversity concerns into REDD+ would benefit in particular from:

1. Syntheses of existing spatial data on biodiversity (focussing in the first instance on forest types and vertebrate groups for which the best information is currently available) for countries and regions where this is still lacking (including much of sub-Saharan Africa), as well as completion of global assessments for other well-studied species groups such as reptiles, plants and well-studied insect taxa (e.g. Odonata, some Lepidoptera).
2. Syntheses and meta-analyses of existing data on biodiversity responses to different types of REDD+ activities. This process should also include the compilation of comparable data on climate (carbon) benefits as well as management and opportunity costs.
3. An improved understanding of the spatial congruencies between carbon and biodiversity in different forest types, and across degradation gradients (essential for our understanding of trade-offs; Baker et al., 2010; Talbot, 2010). This work would probably require the collection of additional field data.
4. An improved understanding of the functional importance of biodiversity in maintaining the long-term resilience of carbon stocks (Thompson et al., 2009).
5. Improved (simplified, robust and replicable) validation procedures for comparing remote-sensing and ground-level biodiversity data to more effectively update and refine our definitions and understanding of different levels of forest degradation, including time-delays in the responses of carbon stocks and biodiversity to forest disturbances.
6. Improved (simplified, robust and replicable) analytical frameworks and software routines for analysing carbon-biodiversity-cost trade-offs over space and across different REDD+ activities, building where appropriate on existing software such as InVest, Marxan and Zonation.
7. Testing and developing (simplified, robust and replicable) Tier 3 field monitoring of biodiversity with the involvement of indigenous people and other local communities (so as to encourage local, evidence-based decision-making and threat reduction), and exploring suitable approaches to link participatory monitoring approaches with national-level monitoring (Danielsen et al., 2011).

Priorities 1 and 2 represent a comprehensive options assessment exercise. Priorities 3 and 4 are genuine research programmes requiring the development of new theory and field data to test existing theory. Priorities 5, 6 and 7 are more technical and are focussed on the development of practical tools that can make effective use of available data and scientific understanding to guide planning and implementation.

Research Priority 4 underpins an important issue in the justification of biodiversity safeguards as part of the REDD+ mechanism

– the notion that biodiversity is critical in maintaining ecological resilience, and hence the long-term permanence of carbon stocks. It is unquestionable that certain threats to biodiversity can have cascading impacts on forest carbon stocks, including the effects of fragmentation (e.g. Laurance et al., 2006) and fire (Barlow and Peres, 2008) on shifts in tree species composition, the effects of herbivore density on tree productivity (Feeley and Terborgh, 2005), and the effects of unsustainable hunting on dispersal processes and the composition of tree recruits (Terborgh et al., 2008). This list is merely indicative, and there are many more relevant studies that have identified strong relationships (Diaz et al., 2009; Thompson et al., 2009). Nevertheless, research attempting to understand the relationship between biodiversity and ecological resilience has been ongoing for more than two decades, and it is extremely difficult to draw firm conclusions owing to the sheer complexity of the problem, and our inability to conduct realistic field-scale experiments in forests. It is very likely that we will still have a poor mechanistic understanding of the links between biodiversity and ecological resilience long after the date when we hope REDD+ will be implemented and operational in developing countries across the tropics. Nevertheless, what is important is that we identify easily quantifiable threatening processes (e.g. unsustainable logging, fragmentation, over-grazing and over hunting and extraction of non-timber resources) that can be linked to key functional elements of a forest ecosystem (e.g. tree density and large mammal abundance) and identify predictable (if not fully understandable) relationships that can be mapped onto estimates of forest degradation with a minimal amount of ground-truthing data. Research is also needed to identify potential thresholds in the relationship between tropical forest biodiversity and forest resilience to climate-related threats such as reduced rainfall or increased temperature.

Finally, it is important to reemphasize that the monitoring of biodiversity safeguards must be viewed not only as a compliance exercise (whatever the verification authority) but also as an invaluable mechanism for learning. Achieving this adaptive cycle is not easy (Gardner, 2010) but essential if new information on forest degradation and relationships between forest carbon and biodiversity is to be cycled back to refine future REDD+ planning and implementation efforts.

5. Conclusions

The challenge of integrating biodiversity concerns into REDD+ is significant. We identify a pathway for progress by distinguishing between different stages of action and requirements for biodiversity data, while also making effective use of the existing IPCC framework for assessing carbon emissions. The main advantage of our framework for integrating biodiversity concerns into the REDD+ process is its viability. Exercises in the spatial mapping of biodiversity and biodiversity-related assessment and monitoring need not be viewed as so complex or expensive that they run the risk of overburdening an already encumbered UNFCCC process. Instead, we argue that progress is already possible for a large number of developing countries, and a gradual, phased approach to implementation can help minimise risks and facilitate the protection of additional biodiversity benefits from REDD+ activities, while encouraging an increased commitment to biodiversity conservation as national capacities improve and develop. Greater coordination between the UNFCCC and CBD, as well as other agencies and stakeholder groups interested in forest conservation are needed if biodiversity safeguards are to be fully adopted and implemented, with appropriate reporting and verification. The biodiversity safeguards adopted in the Cancun Agreements need to be viewed as an opportunity – for securing both the long-term resilience of carbon stocks and additional benefits for biodiversity – rather than a burden. We hope that this paper provides a roadmap for some of the next steps in achieving this vision, and in helping REDD+ programmes to conserve forest biodiversity across the developing world.

Acknowledgements

Authors are grateful to the following agencies for funding whilst this work was conducted: TAG to the Natural Environment Research Council, NERC (NE/F01614X/1), TAG, JB, EB, JF, AL, LP and IV to the Instituto Nacional de Ciência e Tecnologia – Biodiversidade e Uso da Terra na Amazônia (CNPq 574008/2008-0), LP and JB to the Darwin Initiative (17-023), JF to the Empresa Brasileira de Pesquisa Agropecuária – Embrapa (SEG: 02.08.06.005.00), EB to Lancaster University, ACL to CAPES, NDB to WWF-USA, the University of Copenhagen and the EU-funded I-REDD+ project including his attendance at the Greening REDD+ workshop in Freiburg (Germany) where some of these ideas emerged, and FD to the EU-funded I-REDD+ project, and IT to WWF-Denmark. We are grateful to Barney Dickson and Günter Mitlacher for valuable comments on previous versions of this manuscript. Financial support to make the paper open access was provided by the Convention on Biological Diversity, WWF-US, WWF-Denmark and Novozymes Denmark.

References

Ansell, F.A., Edwards, D.P., Hamer, K.C., 2011. Rehabilitation of logged rain forests: avifaunal composition, habitat structure, and implications for biodiversity-friendly REDD. Biotropica 43, 504–511.

Baker, T.R., Jones, J.P.G., Rendo, O.R., Castillo, D., Aguilar, I.C., Torres, J., Healey, J.R., 2010. How can ecologists help realise the potential of payments for carbon in tropical forest countries? Journal of Applied Ecology 47, 1159–1165.

Barlow, J., Peres, C., Henriques, L., Stouffer, P., Wunderle, J., 2006. The responses of understorey birds to forest fragmentation, logging and wildfires: an Amazonian synthesis. Biological Conservation 128, 182–192.

Barlow, J., Gardner, T.A., Araujo, I.S., Avila-Pires, T.C., Bonaldo, A.B., Costa, J.E., Esposito, M.C., Ferreira, L.V., Hawes, J., Hernandez, M.I.M., Hoogmoed, M.S., Leite, R.N., Lo-Man-Hung, N.F., Malcolm, J.R., Martins, M.B., Mestre, L.A.M., Miranda-Santos, R., Nunes-Gutjahr, A.L., Overal, W.L., Parry, L., Peters, S.L., Ribeiro-Junior, M.A., da Silva, M.N.F., da Silva Motta, C., Peres, C.A., 2007. Quantifying the biodiversity value of tropical primary, secondary, and plantation forests. Proceedings of the National Academy of Sciences of the United States of America 104, 18555–18560.

Barlow, J., Peres, C.A., 2008. Fire-mediated dieback and compositional cascade in an Amazonian forest. Philosophical Transactions of the Royal Society B – Biological Sciences 363, 1787–1794.

Beukema, R., Danielsen, F., Vincent, G., Hardiwinoto, S., Andel, J.v., 2007. Plant and bird diversity in rubber agroforests in the lowlands of Sumatra, Indonesia. Agroforest Systems 70, 217–242.

Berry, N.J., Phillips, O.L., Lewis, S.L., Hill, J.K., Edwards, D.P., Tawatao, N.B., Ahmad, N., Magintan, D., Khen, C.V., Maryati, M., Ong, R.C., Hamer, K.C., 2010. The high value of logged tropical forests: lessons from northern Borneo. Biodiversity and Conservation 19, 985–997.

Busch, J., Godoy, F., Turner, W.R., Harvey, C.A., 2011. Biodiversity co-benefits of reducing emissions from deforestation under alternative reference levels and levels of finance. Conservation Letters 4, 101–115.

CBD, 2010. Outcomes of the Global Expert Workshop on Biodiversity Benefits of Reducing Emissions from Deforestation and Forest Degradation in Developing Countries. Convention on Biological Diversity, UNEP/CBD/WS-REDD/1/3, Nairobi, Kenya.

CBD, 2011a. REDD-Plus and Biodiversity. Technical Series No. 59. Convention on Biological Diversity, Montreal, Canada.

CBD, 2011b. Submission by the Secretariat of the Convention on Biological Diversity to the Secretariat of the United Nations Framework Convention on Climate Change. Convention on Biological Diversity, September 26 2011. Montreal, Canada.

CCBA, 2008. Climate, Community & Biodiversity Project Design Standards Second Edition. CCBA, Arlington, VA. December, 2008. <www.climate-standards.org>.

Danielsen, F., Balete, D.S., Poulsen, M.K., Enghoff, M., Nozawa, C.M., Jensen, A.E., 2000. A simple system for monitoring biodiversity in protected areas of a developing country. Biodiversity and Conservation 9, 1671–1705, www.monitoringmatters.org.

Danielsen, F., Skutsch, M.D., Burgess, N.D., Jensen, P.M., Andrianandrasana, H., Karky, B., Lewis, R., Lovett, J.C., Massao, J., Ngaga, J., Phartiyal, P., Poulsen, M.K., Singh, S.P., Solis, S., Sørensen, M., Tewari, A., Young, R., Zahabu, E., 2011. At the heart of REDD: a role for local people in monitoring forests? Conservation Letters 4, 158–167, www.monitoringmatters.org.

Dent, D.H., Joseph Wright, S., 2009. The future of tropical species in secondary forests: a quantitative review. Biological Conservation 142, 2833–2843.
Diaz, S., Hector, A., Wardle, D.A., 2009. Biodiversity in forest carbon sequestration initiatives: not just a side benefit. Current Opinion in Environmental Sustainability 1, 55–60.
Edwards, D., Fisher, B., Boyd, E., 2010. Protecting degraded rainforests: enhancement of forest carbon stocks under REDD. Conservation Letters 3, 313–316.
Epple, C., Dunning, E., Dickson, B., Harvey, C., 2011. Making Biodiversity Safeguards for REDD + Work in Practice – Developing Operational Guidelines and Identifying Capacity Requirements. United Nations Environment Program – World Conservation Monitoring Centre. Cambridge, UK.
FAO, 2011. Assessing Forest Degradation: Towards the Development of Globally Applicable Guidelines. Food and Agriculture Organization, Rome, Italy.
Feeley, K.J., Terborgh, J.W., 2005. The effects of herbivore density on soil nutrients and tree growth in tropical forest fragments. Ecology 86, 116–124.
Fisher, B., Lewis, S.L., Burgess, N.D., Malimbwi, R.E., Munishi, P.K., Swetnam, R.D., Kerry Turner, R., Willcock, S., Balmford, A., 2011. Implementation and opportunity costs of reducing deforestation and forest degradation in Tanzania. Nature Climate Change 1, 161–164.
Garden, J.G., McAlpine, C.A., Possingham, H.P., Jones, D.N., 2007. Using multiple survey methods to detect terrestrial reptiles and mammals: what are the most successful and cost-efficient combinations? Wildlife Research 34, 218–227.
Gardner, T.A., Barlow, J., Araujo, I.S., Avila-Pires, T.C., Bonaldo, A.B., Costa, J.E., Esposito, M.C., Ferreira, L.V., Hawes, J., Hernandez, M.I.M., Hoogmoed, M.S., Leite, R.N., Lo-Man-Hung, N.F., Malcolm, J.R., Martins, M.B., Mestre, L.A.M., Miranda-Santos, R., Overal, W.L., Parry, L., Peters, S.L., Ribeiro-Junior, M.A., da Silva, M.N.F., da Silva Motta, C., Peres, C.A., 2008. The cost-effectiveness of biodiversity surveys in tropical forests. Ecology Letters 11, 139–150.
Gardner, T.A., Barlow, J., Chazdon, R., Ewers, R.M., Harvey, C.A., Peres, C.A., Sodhi, N.S., 2009. Prospects for tropical forest biodiversity in a human-modified world. Ecology Letters 12, 561–582.
Gardner, T.A., 2010. Monitoring Forest Biodiversity: Improving Conservation through Ecologically Responsible Management. Earthscan, London, UK.
GEO BON, 2011. Adequacy of Biodiversity Observation Systems to Support the CBD 2020 Targets. A Report Prepared by the Group on Earth Observations Biodiversity Observation Network (GEO BON), for the Convention on Biological Diversity. GEO BON, Pretoria, South Africa. Published as UNEP/CBD/AHTEG-SP-Ind/1/INF/1, 20 May 2011.
Ghazoul, J., Butler, R., Mateo-Vega, J., Koh, L.P., 2010. REDD: a reckoning of environment and development implications. Trends in Ecology and Evolution 25, 396–402.
Gibson, L., Lee, M.L., Koh, L.P., Brook, B.W., Gardner, T.A., Barlow, J., Peres, C.A., Bradshaw, C.J.A., Laurance, W.F., Lovejoy, T.E., Sodhi, N.S., 2011. Primary forests are irreplaceable for sustaining tropical biodiversity. Nature 478, 378–381.
GOFC-GOLD, 2010. A Sourcebook of Methods and Procedures for Monitoring and Reporting Anthropogenic Greenhouse Gas Emissions and Removals Caused by Deforestation, Gains and Losses of Carbon Stocks in Forests Remaining Forests, and Forestation. GOFC-GOLD Report version COP 16-1, Alberta, Canada.
Harvey, C.A., Dickson, B., Kormos, C., 2010. Opportunities for achieving biodiversity conservation through REDD. Conservation Letters 3, 53–61.
Herold, M., Román-Cuesta, R.M., Mollicone, D., Hirata, Y., Van Laake, P., Asne, G.P., Souza, C., Skutsch, M., Avitabile, V., MacDicken, K., in press. Options for Monitoring Historical Carbon Emissions from Forest Degradation in the Context of REDD+. Carbon Balance and Management Journal.
Holl, K.D., Aide, T.M., 2011. When and where to actively restore ecosystems? Forest Ecology and Management 261, 1558–1563.
IPCC, 2006. Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change. IGES, Japan.
Khan, M.S.I., 2011. Prioritizing REDD+ sites in Tanzania. MSc Thesis. Forest and Landscape Department, Faculty of Life Sciences, Copenhagen University, Denmark.
Laurance, W.F., Nascimento, H.E.M., Laurance, S.G., Andrade, A.C., Fearnside, P.M., Ribeiro, J.E.L., Capretz, R.L., 2006. Rain forest fragmentation and the proliferation of successional trees. Ecology 87, 469–482.
Meridian Institute, 2009a. Reducing Emissions from Deforestation and Forest Degradation (REDD): An Options Assessment Report. Meridian Institute, Washington, DC, USA.
Meridian Institute, 2009b. REDD+ Institutional Options Assessment: Developing an Efficient, Effective and Equitable Institutional Framework for REDD+ under the UNFCCC. Meridian Institute, Washington DC, USA.
Meridian Institute, 2011. Modalities for REDD + Reference Levels: Technical and Procedural Issues. Meridian Institute, Washington, DC, USA.
Miles, L., Kapos, V., 2008. Reducing greenhouse gas emissions from deforestation and forest degradation: global land-use implications. Science 320, 1454–1455.
Moss, N., Nussbaum, R., 2011. A Review of three REDD+ Safeguards Initiatives. Forest Carbon Partnership and UN REDD.
Nichols, E., Larsen, T.B., Spector, S., Davis, A.L.V., Escobar, F., Favila, M., Vulinec, K., 2007. Global dung beetle response to tropical forest modification and fragmentation: a quantitative literature review and meta-analysis. Biological Conservation 137, 1–19.
Pardini, R., Bueno, A.d.A., Gardner, T.A., Prado, P.I., Metzger, J.P., 2010. Beyond the fragmentation threshold hypothesis: regime shifts in biodiversity across fragmented landscapes. PLoS ONE 5 (10), e13666. doi:10.1371/journal.pone.0013666.
Peterson, A.L., Gallagher, L.A., Huberman, D., Mulder, I., 2011. Seeing REDD: conserving biodiversity and reducing emissions by avoiding deforestation. Journal of Sustainable Forestry 31, 2–3.
Pistorius, T., Schmitt, C.B., Benick, D., Entenmann, S., 2011. Greening REDD+ Challenges and Opportunities for Forest Biodiversity Conservation. Policy Paper, Second Revised Edition. Freiburg, Germany.
Pitman, N., 2011. Social and Biodiversity Impact Assessment Manual for REDD+ Projects: Part 3 Biodiversity Impact Assessment Toolbox. Forest Trends, Climate, Community & Biodiversity Alliance, Rainforest Alliance and Fauna & Flora International. Washington, DC, USA.
Putz, F.E., Redford, K.H., 2009. Dangers of carbon-based conservation. Global Environmental Change 19, 400–401.
Rey Benayas, J.M., Newton, A.C., Diaz, A., Bullock, J.M., 2009. Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis. Science 325, 1121–1124.
Ring, I., Drechsler, M., Teeffelen, A.J., van Irawan, S., Venter, O., 2010. Biodiversity conservation and climate mitigation: what role can economic instruments play? Current Opinion in Environmental Sustainability 2, 50–58.
Sasaki, N., Asner, G.P., Knorr, W., Durst, P.B., Priyadi, H.R., Putz, F.E., 2011. Approaches to classifying and restoring degraded tropical forests for the anticipated REDD plus climate change mitigation mechanism. Forest Biogeosciences and Forestry 4, 1–6.
Scharlemann, J., Kapos, V., Campell, A., Lysenko, I., Burgess, N., Hansen, M., Gibbs, H., Dickson, B., Miles, L., 2010. Securing tropical forest carbon: the contribution of protected areas to REDD. Oryx 44, 352–357.
Schmitt, C.B., 2011. A tough choice: approaches towards the setting of global conservation priorities. In: Zachos, F.E., Habel, J.C. (Eds.), Biodiversity Hotspots. Springer Publishers, London, pp. 23–42.
Sodhi, N.S., Lee, T.M., Koh, L.P., Brook, B.W., 2008. A meta-analysis of the impact of anthropogenic forest disturbance on Southeast Asia's Biotas. Biotropica 41, 103–109.
Stickler, C., Nepstad, D.C., Coe, M.T., Mcgrath, D.G., Rodrigues, H.O., Walker, W.S., Soares-Filho, B., Davidson, E.A., 2009. The potential ecological costs and cobenefits of REDD: a critical review and case study from the Amazon region. Global Change Biology 15, 2803–2824.
Strassburg, B., Turner, R.K., Fisher, B., Schaeffer, R., Lovett, A., 2009. Reducing emissions from deforestation – the "combined incentives" mechanism and empirical simulations. Global Environmental Change – Human and Policy Dimensions 19, 265–278.
Talbot, J.D., 2010. Carbon and Biodiversity Relationships in Tropical Forests. Multiple Benefits Series 4. UNEP World Conservation Monitoring Centre, Cambridge, UK.
TEEB, 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the Approach, Conclusions and Recommendations of TEEB.
Teobaldelli, M., Doswald, N., Dickson, B., 2010. Relationship and Synergies between Monitoring Systems for Carbon Stock Change and Multiple Benefits REDD+, Carbon & UNEP World Conservation Monitoring Centre, Cambridge, UK.
Terborgh, J., Nunez-Iturri, G., Pitman, N.C.A., Valverde, F.H.C., Alvarez, P., Swamy, V., Pringle, E.G., Paine, C.E.T., 2008. Tree recruitment in an empty forest. Ecology 89, 1757–1768.
Thompson, I., Mackey, B., McNulty, S., Mosseler, S., 2009. Forest Resilience, Biodiversity, and Climate Change. A Synthesis of the Biodiversity/Resilience/Stability Relationship in Forest Ecosystems. Montreal, Canada.
Venter, O., Laurance, W.F., Iwamura, T., Wilson, K.A., Fuller, R.A., Possingham, H.P., 2009. Harnessing carbon payments to protect biodiversity. Science 326, 1368.
Wendland, K.J., Honzák, M., Portela, R., Vitale, B., Rubinoff, S., Randrianarisoa, J., 2010. Targeting and implementing payments for ecosystem services: opportunities for bundling biodiversity conservation with carbon and water services in Madagascar. Ecological Economics 69, 2093–2107.
Wilson, K.A.W., Eijaard, E.M., Rummond, S.D., Rantham, H.S.G., Oitani, L.B., Atullo, G.C., Hristie, L.C., Enter, O.V., Atts, M.W., 2010. Conserving biodiversity in production landscapes. Ecological Applications 20, 1721–1732.

APPENDIX XXII

Danielsen, F., Balete, D., Poulsen, M.K., Enghoff, M., Palaganas, V., Nozawa, C. and Jensen A.E. 2001.
Biodiversity Monitoring System Manual for Protected Areas.
The World Bank, Danida, Department of Environment and Natural Resources, Manila and NORDECO, Copenhagen. 1–78 pp. 2nd edition.

Biodiversity Monitoring System

Manual

for Protected Areas

February 2001

The World Bank
Danida
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Acknowledgements

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Sources of inspiration	Kunkle, S., Johnson, W.S. & Flora, M. 1987. Monitoring stream water for land-use impacts: A training manual for natural resource management specialists. Water Resources Division, US National Park Service. 102 pp. McManus, J.W., Ablan, M.C.A., Vergara, S.G., Vallejo, B.M., Menez, L.A.B., Reyes, K.P.K., Gorospe, M.L.G. & Halmarick, L. 1997. ReefBase aquanaut survey manual. ICLARM Educ. Ser. 18. 61 pp. Bibby, C.J., Burgess, N.D. & Hill, D.A. 1992. Bird Census Techniques. Academic Press. 256 pp.

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Preface

Welcome to the DENR Biodiversity Monitoring Manual! The Biodiversity Monitoring System methods have been designed to help you contribute to the improved conservation and sustainable use of forests and freshwater and marine wetlands. We have aimed to develop a set of useful and workable standard methods. We hope that this manual will not only help you survey and monitor protected areas using the methods described, but also encourage your interest in contributing to the conservation of biodiversity.

This manual offer information on biodiversity monitoring to enable you to carry out your work using the Biodiversity Monitoring System as prescribed in the DENR Administrative Order shown on the back cover.

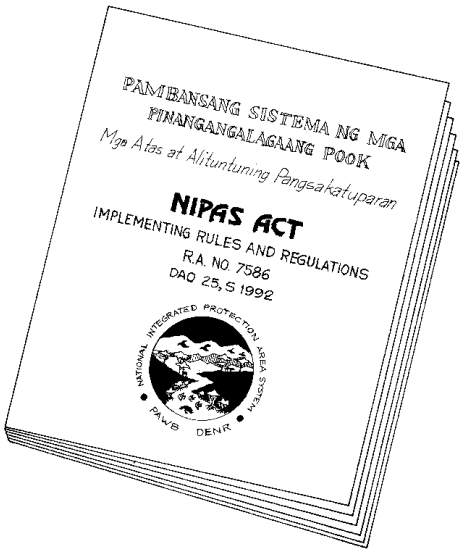
The BMS: a minimum starting point. Biodiversity in a protected area encompasses thousands of life-forms, many of them not even named and described, yet the resources and people available to manage and monitor biodiversity are limited. The Biodiversity Monitoring System is a minimum starting point, which we hope will further evolve over time. The methods developed are a compromise between the financial resources available for monitoring purposes and the aim of ensuring that no major change in a protected area's biodiversity can go undetected. The methods are based on locally available people, equipment and funds.

Later when this monitoring system is in operation in more areas and additional resources are made available, it is advisable that the methods are backed up by satellite-based monitoring of land-use on a regular basis as well as in-depth monitoring of selected habitats and species. Since all data will be compiled on a geographical basis (with latitude and longitude wherever possible), the data can be entered into a computerised 'GIS'-database. In the future, when data can be stored and analysed on computers, perhaps Transect data could even be used by the Protected Areas and Wildlife Bureau to reveal national trends in the populations of species of priority to conservation.

1. Introduction

Why monitor biodiversity? Protected areas have been established to conserve the Philippine *samut-saring buhay* or 'biodiversity'. Repeated data sampling or 'monitoring' can show if the biodiversity of an area is being maintained in accordance with the NIPAS Act and the management objectives of the area.

Questions monitoring can answer. Monitoring of biodiversity can answer questions such as:



- Are habitats and ecosystems being degraded?
- Are the populations of threatened species of plants and animals declining?
- What are the causes?
- Has management intervention had the intended impact on the ecosystem?
- Are there increased benefits to local communities from sustainable natural resource use?

In other words, monitoring can answer if the management interventions in the area are effective in addressing biodiversity conservation.

Existing monitoring activities. Many protected area communities, especially indigenous people, implement traditional systems for controlling access to resources (Box 1-1). Sometimes this is based on generations of experience with resource use. The BMS was designed to build upon and strengthen existing community-based monitoring.

Box 1-1. Example of indigenous monitoring activity.

> Indigenous people who have lived in a particular area for generations often have intimate knowledge of the habitats and behaviour of wildlife species. Observing events in nature influences their survival strategies and resource use.
>
> In several protected areas, community leaders and people regularly discuss the availability and quality of natural resources. One such example is the Talaandigs and Higaonon in Mt. Kitanglad Range Natural Park who perform rituals for hunting and forbid resource extraction in some places which are called *lalaw*. In this way they control and monitor access to certain areas and the use of resources. Merely by living in the area, using the resources and observing their environment, they monitor changes in the resources.

2. What is the Biodiversity Monitoring System?

Objectives. The Biodiversity Monitoring System aims to improve the information available for decision-makers in protected areas through the regular collecting of data on natural biological resources and their utilisation. The focus is on *identifying trends* in biodiversity and its use - *so as to guide action* in protected area management.

In addition, the BMS is intended to improve the participation of protected area communities in protected area management.

Who can undertake biodiversity monitoring? Anyone interested in gathering information on the environment and its use can monitor biodiversity. The BMS is particularly designed for use by PA staff, local communities, local environmental groups and deputized forest guards.

How will the monitoring information be used? The information you gather will be analysed by yourself or by the Coordinator of the BMS of the Protected Area Office. The results will be used by the Protected Area Management Board (PAMB) and the local government in order to take better decisions on the management of the land and the people in the protected area (Box 2-1). Some of the information will alert the PASu or the CENRO in charge about situations that should be examined further. The information will also be used by the protected area communities to improve local resource management together with the PA staff.

Box 2-1. What can the PAMB expect from the monitoring system?

The BMS can provide valuable data to the PAMB that will enable them to make informed and sound decisions as to how to better manage the protected area resources. Through the BMS, the PAMB can better determine the effectiveness of:

- livelihood programs on natural resource use
- resource use permits
- establishment of sanctuaries and seasonal closures
- municipal ordinances, and other management interventions on the part of the PAMB and the local government in addressing the threats to the PA.

In addition, the BMS encourages a dialogue between the PA staff and the PA communities regarding the status of PA resources and management. As a result of this, the communities are more likely to agree on, and participate in, regulation of resource use, reaction to encroachment by outsiders, and law enforcement.

3. Organizing biodiversity monitoring

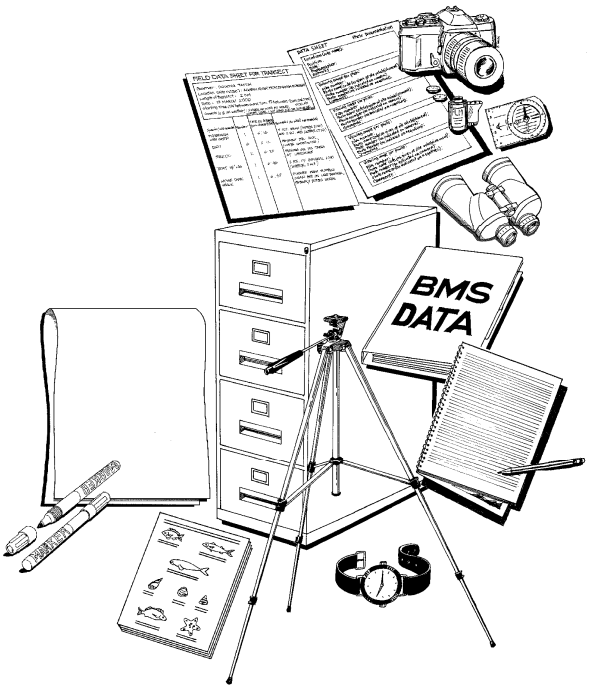
How should the field implementation be organized? At the protected area level, the Biodiversity Monitoring System is headed by the PA Superintendent (PASu) or CENRO in charge. Implementation is undertaken by regular DENR staff assigned by Special Order with monitoring and patrolling as part of their Key Result Area. These staff are normally selected among protected area, CENRO and PENRO staff. Among them, a BMS Coordinator is designated to coordinate and oversee the overall implementation of the monitoring system. The BMS Coordinator should be a permanent staff member. The team reports to the PASu, who in turn reports to the Protected Area Management Board, the PENRO and the Regional Executive Director of DENR.

It is the task of the BMS Coordinator to ensure that:

- BMS sites are monitored in accordance with the BMS Implementation Plan
- the methods are used in accordance with the Manual
- each transect route is surveyed by the same observer every quarter
- all data are submitted to the PA Office immediately upon return from field
- BMS equipment and data are properly stored
- Field Diary data and other BMS results are regularly discussed among PA staff to ensure high quality
- sufficient notes are made to document sightings of rare species
- BMS data are organized, analysed, interpreted and presented to PAMB with proposed management actions
- copies of the quarterly BMS standard report to PAMB are submitted to the Regional DENR
- photos are used for demonstration and education purposes whenever possible
- BMS achievements are properly documented.

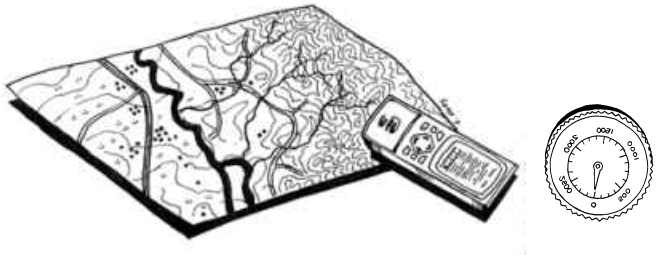
In most protected areas, PA staff are too few to implement the monitoring system in full. It is important to engage deputized forest rangers, indigenous people and volunteer community groups to assist the PA staff or conduct some of the monitoring methods on behalf of the PA management.

What equipment do you need? To monitor biodiversity using the Biodiversity Monitoring System, some basic equipment will be needed:



- notebook and pencils
- markers and large sheets of paper
- binoculars
- SLR camera with batteries and film
- a tripod
- a watch
- compass
- ring binders and filing cabinet for data storage
- Photo Documentation forms
- Transect data sheets
- identification guide

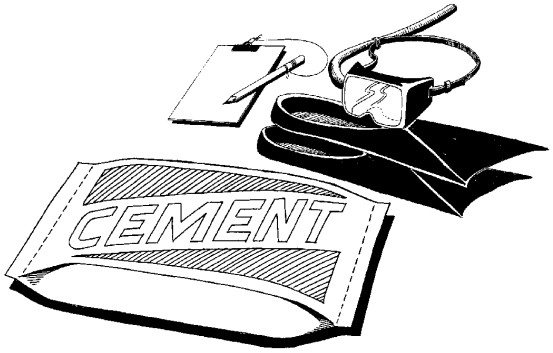
When setting up the Biodiversity Monitoring System, we also recommend that you have access to:



- topographic map of the area
- GPS (Global Positioning System receiver)
- altimeter

In addition, for the Transect Swim method in marine areas, you need:

- mask
- snorkel
- fins
- plastic writing slate (or plastic laminated Transect data sheet)
- cement for establishing permanent markers on the sea bed.



4. Budget requirements

Apart from the initial costs of purchasing equipment, the most expensive items when monitoring biodiversity are staff time and travel. Like patrolling, biodiversity monitoring is a basic and regular protected area function. It should be included in the DENR's proposed core budget every year (Box 4-1).

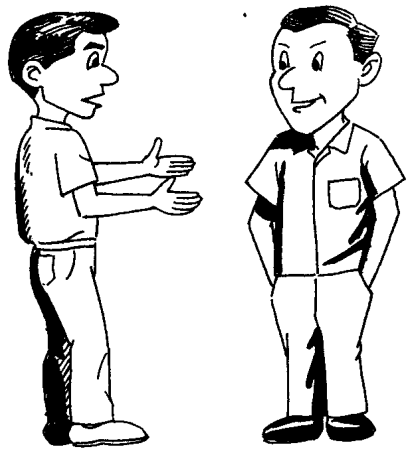
Box 4-1. The budget planning process of the government.

It is the responsibility of the PASu together with the Protected Areas and Wildlife Division (PAWD) Chief to ensure that the BMS budget in your PA is included in the annual funds set aside for the regional office.

This is the process:
1. Budget call (January-March)
2. DENR prepare and submit budget proposal (April-June)
3. Technical Budget Hearing
4. Revised budget to the President (July-September)
5. DENR budget approved
6. National Reprogramming Conference (October-December)

When the budget of the DENR is approved, a national reprogramming conference is held to identify the Banner Programs and/or Key Result Area (KRA). During this time all the PAWD Chiefs and the senior staff of the Protected Areas and Wildlife Bureau (PAWB) discuss and agree on the protected area and wildlife KRA of the regional offices.

For some protected areas, the financial requirements are indicated in their Protected Area Act and the PA budget is automatically included in the annual DENR budget appropriation. An indicative budget for biodiversity monitoring in an average PA is provided in Annex 3.



5. Ten steps in implementing biodiversity monitoring

The Biodiversity Monitoring System comprises ten steps to be followed in each PA:

Step 1 Compile basic information on the protected area

Before you can establish and use the Biodiversity Monitoring System, you should have at least a rough idea of what the major threats to the PA are and where they are most serious. In addition, you should know which parts of the area are particularly important to conservation and local use by PA communities. These can, for instance, be areas known to support species of conservation interest, or where local people fish, hunt and collect non-timber forest and wetland products, as well as areas under resource use permits.

Step 2 Identify priorities for biodiversity monitoring

Write down the names of those areas and those resource uses and species that should be monitored (Chapter 13). Discuss your list with the PASu or CENRO in charge, the PAMB and other knowledgeable people, including representatives of indigenous people and other local communities. Decide which areas, resource uses and species are the most important to monitor.

Step 3 Training

Request the Protected Area Wildlife Division of the Regional DENR or the PAWB for training in the Biodiversity Monitoring System. They may be able to provide a trainer, or they can get staff from other protected areas to assist you.

Step 4 Establish the Biodiversity Monitoring System

The Biodiversity Monitoring System entails four main methods:

- Focus Group Discussion
- Field Diary
- Photo Documentation
- Transect (Walk, Cruise and Swim)

Look at the list of the most important areas, resource uses and species you need to monitor. Read up about the methods in this manual and identify which areas and species can best be monitored by each method. Your choice will depend on the level of threat, your available time, number of PA staff and volunteers, funds and transport facilities. Establish monitoring sites in the field (Focus Group Discussion, Photo Documentation, Transect).

Be sure you know your priority resource uses and species. If necessary, prepare a simple guide for the field identification of your priority species, using available existing literature (ask PAWB for assistance).

Step 5 Compile data using the field methods

Use the field methods to compile data on resource use and biodiversity. Write a Field Diary whenever you and the other BMS staff and volunteers are on patrol or travelling in the PA. Use the other methods every quarter of the year.

Store the data sheets and photos carefully in ring binders and photo albums in a separate BMS filing cabinet at the Protected Area Office. Prepare copies of the Transect data sheets and submit them to the PENRO for safe storage.

Step 6 Analyse data and identify trends

Every quarter, look at your data and try to highlight any changes over time (Chapter 14). If there seem to be changes, you should assess whether the data is likely to reflect the true situation in the PA or if the data could be biased, for instance by a change in monitoring routines or the weather.

If there seems to be a real change, try to identify the reason for the change, the importance of the change, and then assess whether any management intervention is appropriate. The reason for a change is often related to the human use of the area. Chapter 15 describes the common impacts of human activities and typical causes of destructive activities in Philippine protected areas.

Step 7 Validate results with the protected area communities

Present the findings to local people in the barangays and request for their advice. Use pictures and figures but very few words, and try to be as site-specific as possible (Annex 1). Do the local people consider the findings relevant? Also, discuss possible actions to be taken by the people themselves, the Protected Area Management Board or the Local Government Units on the basis of the BMS findings. Maintaining a dialogue with the PA communities is a very important part of the monitoring process (Figure 5-1).

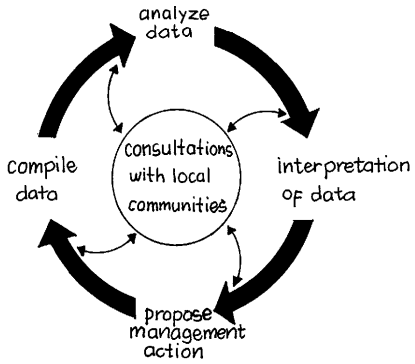


Figure 5-1. The flow of information in the Biodiversity Monitoring System.

Step 8 Present the findings and recommended actions to the PAMB

Present the most significant findings to the decision-makers in the Protected Area Management Board. Focus on trends. Present corresponding options for actions including draft resolutions. How you display your findings is very important (Chapter 16). Use maps, graphs, figures and few words (Annex 1).

Step 9 Make decisions to improve protected area management

Remember that the reason for spending time and money on monitoring biodiversity is to guide action in PA management in order to maintain the biodiversity. You should encourage the Protected Area Management Board to take decisions on the basis of the BMS findings. A list of possible management interventions is offered in Chapter 15.

Step 10 Revise and strengthen the monitoring system

One year after establishment of the system, assess whether the methods provided useful data or not, find out why, and then adjust the monitoring system. Perhaps a method generated too few data, or it did not cover the threatened areas it should have. Or perhaps some PA staff or volunteers were not fully committed to the work, and the task of monitoring biodiversity needs to be given to somebody else.

6. Choice of field methods

The Biodiversity Monitoring System methods have been selected because they are the easiest and most cost-effective to use. They encourage a constructive dialogue between local communities and protected area staff. They are appropriate to the people and resources locally available in most protected areas.

You should prioritize:

- The Focus Group Discussion method
- The conducting of a regular Field Diary
- The Photo Documentation method.

The Transect method should only be established in areas where you are sure that your priority species are present. If the protected area is short of staff, use less than one third of the time and resources available for monitoring on the Transect method.

Box 6-1 to 6-3 describe recommended methods in land, freshwater wetland, and marine areas.

Box 6-1. Recommended BMS methods in land areas.

In land areas, use of the following methods is recommended:

- Focus Group Discussion
- Field Diary
- Photo Documentation
- Transect Walk

Box 6-2. Recommended BMS methods in freshwater wetlands.

In freshwater wetlands, use of the following methods is recommended:

- Focus Group Discussion to monitor the fishery and status of freshwater habitats
- Field Diary
- Photo Documentation above water (in undulating terrain such as river valleys and along the shoreline of lakes and swamps)
- Transect,
  - in dry areas: by walking on foot (Transect Walk);
  - in wet areas: by using a boat along rivers and shorelines of lakes (Transect Cruise)

Box 6-3. Recommended BMS methods in marine wetlands.

In marine wetlands, use of the following methods is recommended:

- Focus Group Discussion to monitor the fishery and status of marine habitats
- Field Diary
- Photo Documentation above water along the coastline
- Transect,
  - in dry areas: by walking on foot (Transect Walk);
  - along mangrove channels and inter-tidal mudflats: by using a boat (Transect Cruise);
  - in coral reefs/seagrass beds: by swimming or using a glass bottom box (Transect Swim).

If the protected area has large financial resources and skilled surface and scuba-divers, they may embark upon more standardized methods for coral reef monitoring such as manta tow and line intercept transect carried out, for instance by volunteer dive clubs. For breeding seabird colonies on islets, it is recommended that you consult PAWB for census method.

In freshwater and marine areas where more than 500 waterbirds regularly occur, it is recommended that you also count waterbird numbers (see Appendix on Waterbird Counts).

Table 6-1. BMS methods for use in land, freshwater and marine habitats.

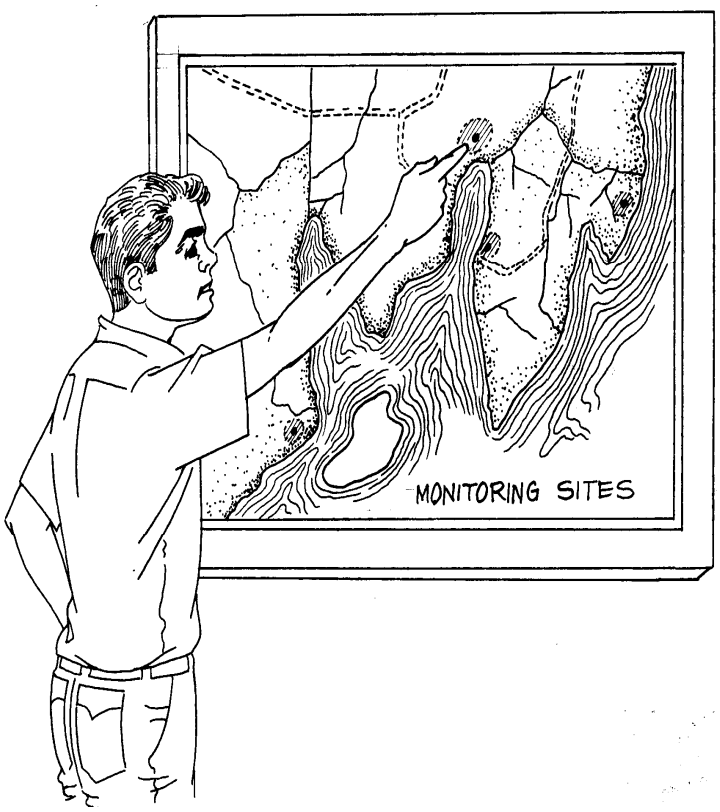
	Focus Group Discussion method	Field Diary method	Photo Documentation method	Transect method
Land area	+	+	+	+ Transect Walk
Fresh-water area	+	+	+ (above water)	+ Transect Walk/Cruise
Marine area	+	+	+ (above water)	+ Transect Swim

+: method applicable

7. Location of monitoring sites

Vast areas of the protected area without the presence of people may not need more than a few monitoring sites. You should establish monitoring sites:

- In seriously threatened areas. For instance, areas with intact natural habitats of priority to conservation (such as old growth forest, wetland and coral reef) in the multiple use and sustainable use zones of the protected area or in areas under user permit, including community resource extraction areas.



- In each municipality so that the local government can benefit from your results. Often PAMB resolutions resulting from your monitoring work will need to be translated into municipal and barangay level ordinances in order to be effective.

- Along regular patrol routes. To save costs, ensure that, whenever possible, biodiversity monitoring sites are located so that they can be visited as part of the regular patrol or community work.

Details on the recommended location of monitoring sites for each method are provided in Chapter 8-12.

8. Focus Group Discussion Method

This method comprises the establishment of a volunteer Community Monitoring Group of local people who are encouraged to collect information on a regular basis between quarterly Focus Group Discussions with PA staff.

Focus Group Discussions and barangay/sitio meetings can generate very important information regarding trends in use of resources, trends in status of selected resources, and trends in the number of households benefiting from the use of resources. The information is mainly based on local communities' own perception of trends. Data gathered continuously from a number of representative communities can provide a valid picture of general trends. For instance, changes in harvest volume per effort can indicate trends in abundance of resources. It can provide an early warning of over-harvesting situations which would threaten local communities' opportunities for sustained resource-use.

This method particularly encourages a constructive dialogue between PA staff and local communities on the status and management of the protected area. The PA communities will be directly involved in biodiversity monitoring. Consequently the communities will become more aware of the need for biodiversity conservation. It is further anticipated that the communities involved agree on, and participate in, law enforcement and regulation of resource use. The monitoring system could also provide input to the community-based resource management plans and possible tenurial contracts between the communities and PAMB and DENR.

EQUIPMENT

The following tools are needed: identification guide, large sheets of paper, markers, snacks.

SUITABILITY

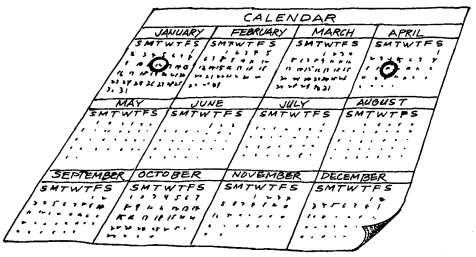
Useful on land and in freshwater and marine areas. In freshwater and marine areas, the method can be used to monitor the fishery (Annex 5) as well as the status of wetland habitats (e.g., through discussions of trends in use of explosives).

PERSONNEL

This method should be undertaken by those PA staff who are not involved in enforcement activities in the same area (so as to encourage open discussion with local people). Two persons are needed, one to facilitate discussions and one to record the minutes. One of them should be a permanent staff member. Skills in Participatory Rural Appraisal (PRA) method are an advantage. Two PA staff can be responsible for 4-6 Community Monitoring Groups, alongside other PA staff duties.

FREQUENCY

A discussion meeting of two hours should be undertaken every quarter with the Community Monitoring Group (Focus Group Discussion). Once a year a meeting should be held with the village (barangay/sitio meeting).



LOCATION OF COMMUNITY MONITORING GROUPS

Community-based biodiversity monitoring groups should ideally be set up in most settlements within the PA. However, it is suggested that in the initial stages of the Biodiversity Monitoring System you focus on:

- Communities living near areas of high conservation value,
- Communities with a relatively high dependence on forest or freshwater/marine products for their livelihood and subsistence. The more dependent they are, the more chance there is of people having valuable information on the resources,
- Communities thought to over-harvest areas of high conservation value, and
- Communities living in areas known to be the entry/exit points of resources.

STEPS IN ESTABLISHING FOCUS GROUP DISCUSSIONS

Focus Group Discussions are to be conducted in a pre-selected and permanent number of barangays or sitios. You should meet with barangay captains or other relevant community leaders to explain the objectives and activities of the monitoring system (Annex 2). You should stress the common interest of PA staff and local people in conservation and also mention the possible use of the monitoring data in a more sustained use of local natural resources.

1 Assisted by the barangay leader, you should identify 10-15 community members among households utilizing the PA biodiversity resources and persons involved in natural resource management (forest guards, community forestry committee members, etc.). Include the most experienced indigenous healer and all-round hunter/forest product gatherers and fisherpeople. Make sure that both men and women from different age groups are represented.

2 From among these, a volunteer Community Monitoring Group of 5-8 people should be established (based on a selection of the most willing and interested). This group should preferably remain the same over a long period of time.

Meeting with Community Monitoring Group

3 Together with the Group, you will agree on what should be monitored.

4 You, as PA staff, should be responsible for conducting regular discussion meetings with the Group in each of the selected barangays/sitios. See the text below on steps in conducting a Focus Group Discussion. You should conduct the discussions as an integral part of your regular work within the PA. You should encourage the Group to collect information and data (and write it down, draw or photograph it, or otherwise record it) on a regular basis between their quarterly discussions/meetings with PA staff.

5 You should give prior notice regarding the group discussions (at least one week) to allow all participants to attend. Make sure that the time set for the meeting is convenient for the participants. For instance, the meeting could be held in the evening when work or household activities are completed. You should also arrange the program and a venue for the meetings.

6 Soon after each meeting, write a report on the meeting. Collate and analyze the data (format for reporting in Annex 4). The report must be presented and discussed at the next quarterly discussions/ meetings between the Group and yourself.

7 You should analyze results from the Focus Group Discussions on a quarterly basis and summarize them for the Head of the Protected Area Office.

8 You should arrange a common meeting at community (barangay/ sitio) level on a regular basis with as much community participation as possible for each area covered by the Group. This will enable the entire community to have access to the results of the biodiversity monitoring trends in their area and enable the communities' inputs and responses to be obtained, leading to agreed mitigating actions.

STEPS IN CONDUCTING FOCUS GROUP DISCUSSION

1 Make sure that you know the objective of the meeting (e.g., to discuss those resource uses and species that have been selected for monitoring by the Group) and how you want to conduct it (who will participate, proposed agenda, etc.).

2 Start the meeting by agreeing on the duration. Then agree on the order in which issues should be addressed. Use possible waiting time before all participants arrive for informal discussions and for taking a look in the members' notebooks. Show a strong interest in the members' notebooks.

3 Show the report you made from the last meeting and discuss it.

4 Go through the resource uses (that you already have decided to monitor) one by one:

(a) let the members present their notes on the specific resource use,
(b) agree on the combined numbers/quantities they have noted,
(c) discuss the perceived trends in the resources,
(d) discuss the trends at the level of extraction,
(e) discuss significant changes,
(f) discuss reasons for changes,
(g) discuss problems and solutions.

During (a) and (b) use the Format 2 matrix for resource uses (Annex 4). During (c)-(g) use the Format 1 on main issues discussed (Annex 4). Repeat the steps for the other main resource uses.

5 Let the members present the list of priority species observed following the Format 3 matrix for species observed (Annex 4). Discuss changes in the observations, if any.

6 Discuss any other relevant matters with the Group that you or they think important.

7 Evaluate the session. See if anything needs to be improved.

8 Agree on the time and place of the next meeting. Draw the meeting to a close.

DATA STORAGE

The report from the meetings (Format 1, 2 and 3, Annex 4) should be stored in a ring-binder and filed in the BMS filing system in the Protected Area Office.

TIPS

1 Ensure that the discussion is a dialogue. You should encourage everyone to participate, including indigenous people. Make sure that direct resource users are given priority as members in the monitoring group. Try to establish and maintain an atmosphere of trust. Focus on fruitful co-operation with people (not laying down the law) and on listening to people (not teaching them).

2 Do not use leading questions ("Is the river water drinkable?") but use open-ended questions ("How is the river water?"). Let the group make their own conclusions of the discussions.

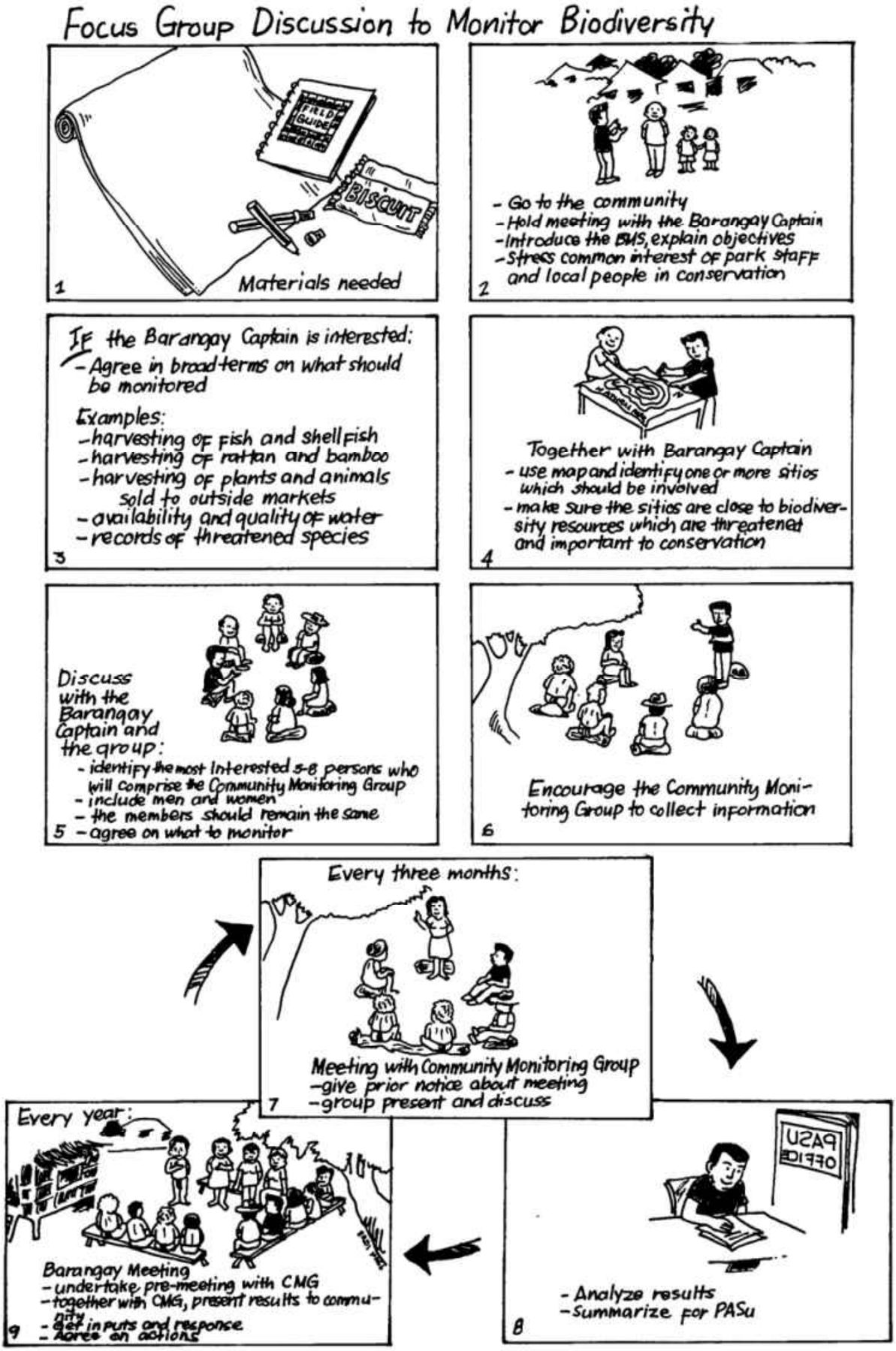
3 If a resource use plan or a development plan is available for the barangay you should know it and include in your discussion the relevant areas of overlap between the plan and the monitoring (such as regulations/actions on fishing/hunting/other land use). Regularly share the outcomes of the Focus Group Discussions with the barangay officials.

4 Do not shy away from reporting the obvious and continue to do this. At some point this may lead to important discoveries that can be used for management purposes. Remember that no changes are also important information.

EXAMPLES OF ISSUES TO BE DISCUSSED

Since last year/last quarter...

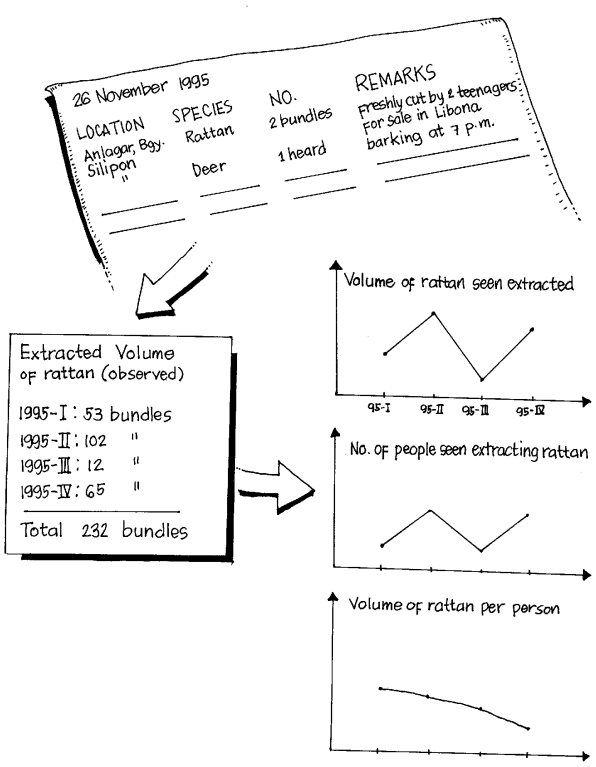
- Has there been any change in time and effort needed to collect a fixed amount of resources such as rattan, firewood, shellfish, freshwater fish, medicinal plants, fruits, wildlife species, etc.?
- If yes, how much more or less effort (time) had to be spent?
- What are the perceived trends in occurrence/abundance of key resources/species?
- What are the possible reasons for the changes?
- What are the problems/solutions to the changes if any?
- Has the quality or average size of the collected resources changed?
- Are resources being used now which have not been harvested previously?
- Have there been any changes in the methods being used for harvesting resources?
- Has the number of people engaged in activities like small-scale logging, kaingin, use of wetland resources, etc. changed during the last quarter (or the last year)?
- Has the number of dealers changed?


Focus Group Discussion to Monitor Biodiversity
FIELD GUIDE
BISCUIT
1
Materials needed
- Go to the community
- Hold meeting with the Barangay Captain
- Introduce the BMS, explain objectives
- Stress common interest of park staff and local people in conservation
2
IF the Barangay Captain is interested:
- Agree in broad terms on what should be monitored
Examples:
- harvesting of fish and shellfish
- harvesting of rattan and bamboo
- harvesting of plants and animals sold to outside markets
- availability and quality of water
- records of threatened species
3
Together with Barangay Captain
- use map and identify one or more sitios which should be involved
- make sure the sitios are close to biodiversity resources which are threatened and important to conservation
4
Discuss with the Barangay Captain and the group:
- identify the most interested 5-8 persons who will comprise the Community Monitoring Group
- include men and women
- the members should remain the same
- agree on what to monitor
5
Encourage the Community Monitoring Group to collect information
6
Every three months:
Meeting with Community Monitoring Group
-give prior notice about meeting
-group present and discuss
7
- Analyze results
-Summarize for PASu
8
Every year:
Barangay Meeting
- undertake pre-meeting with CMG
- together with CMG, present results to community
- get inputs and response
- Agree on actions
9

9. Field Diary Method

This method comprises standardized recording of routine observations on resource use, habitat and wildlife in a simple pocketbook or data sheet during regular patrols in the PA. It encourages a routine of making daily accounts of observations.

All you need is to record in writing your observations when you are in the field. This will encourage you to be observant of changes in the use of PA resources, in the location of threats, and in the abundance of priority species in the PA.



EQUIPMENT

Only a notebook, a pencil and binoculars are needed, but an identification guide is also useful.

SUITABILITY

Useful in land, freshwater and marine areas.

PERSONNEL

Protected area rangers, deputized forest guards and the assigned BMS staff should use a Field Diary when they are in the field. The BMS Coordinator is responsible for ensuring this.

FREQUENCY

It is recommended that all PA staff undertake Field Diary reporting whenever they are in the field. The BMS Coordinator is responsible for this.

LOCATION OF MONITORING SITES

A Field Diary is used on the regular patrol routes.

HOW AND WHAT TO WRITE IN A FIELD DIARY

1 Write your name, date and general locality (sitio/barangay) of the site you are visiting or patrolling (Box 9-1). Always start your diary on a clean page.

2 When recording people encountered and their activities (reason why they are in the area), you should note:

- the type of products gathered (orchids, rattan, fruits, leaves, shells, fish, etc.) and wildlife in their possession,
- their quantity,
- the use, and
- the market price where possible (if for selling).

If you see people engaged in major unsustainable activities (mining, large-scale logging, destructive fishing, constructing buildings and roads without permits, large-scale extraction of resources without permit etc.), note the number of people and what they are doing.

3 When recording signs of people's presence in the PA, note the type of disturbance, such as:

- cut/sawn logs,
- discarded remains of hunted wildlife such as bird feathers and bat skins (count heads if possible),
- sound of chainsaws (how many) or major cutting of trees,
- forest fires,
- smoke from kaingin,
- recent forest clearings (type of forest, size in hectares, and exact location), and
- large amounts of garbage.

If immediate management intervention is needed and you have a camera, take photos to document your observations.

4 When recording wildlife, note:

- the type of record (seen, heard, tracks found),
- the estimated numbers of individuals,
- the habitat, and
- the location.

For unfamiliar species, it is desirable that a sketch of the animal be made emphasizing distinguishing features such as color, shape of beak, relative size (length or height), etc.

5 When recording physical changes (natural or caused by humans) in the landscape, such as eroded banks, landslides, new logging roads, mining exploration, quarrying or excavations, note the exact location of the observed disturbance. If you have a camera, take photos of the most important observations.

6 Second-hand information (what you are told, but you have not seen yourself) should also be noted in the Field Diary. Note always who gave the information. See the list of priority resource uses and species for your PA.

7 At the end of the day or after completion of each routine patrol round, a separate page in the Field Diary is allotted for a tally of all observations, arranged according to appropriate categories. The Field Diary data should be submitted to the PA Office immediately upon return from the field.

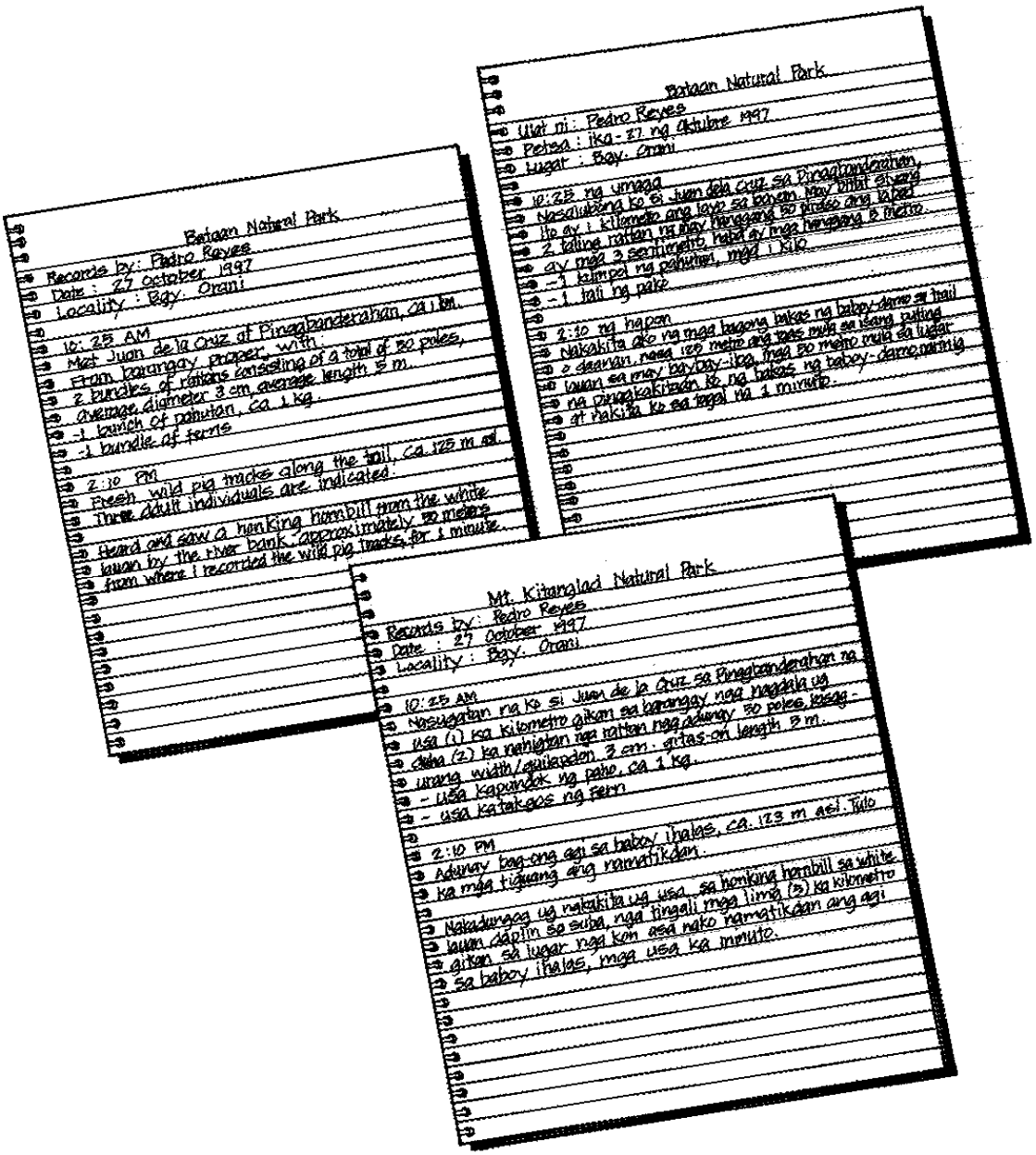
DATA STORAGE AND MANAGEMENT

Store your notebook carefully. If you are using separate sheets of paper (data sheets), file them in a ring-binder in the biodiversity monitoring filing system and never bring used data sheets to the field again.

TIPS

1 Always use good quality paper
2 Never use ball-point pen as its ink tend to fade or run when wet. A good quality pencil of medium point, no. 2 or 3, is useful.
3 Store your field notes in a water-proof container such as a plastic bag while travelling.
4 Always write in short, concise sentences.
5 It will often be useful to be able to locate the exact place where human activities (e.g. kaingin, recent forest clearings, etc.) or rare wildlife were recorded again. Note the exact location (name of river, distance from nearest community center or from prominent features in the landscape, elevation, co-ordinates).
6 The BMS Coordinator should regularly discuss the Field Diary information with the PA staff to ensure high quality.

Box 9-1. Example of a Field Diary
(English, Tagalog and Visayan)

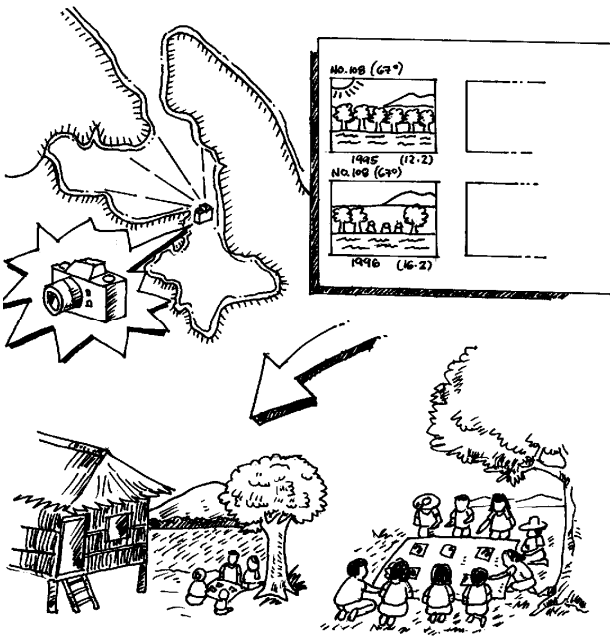


10. Photo Documentation

This method entails on-the-ground fixed point photographing of selected hillsides in priority forest blocks at regular intervals.

Monitoring of major changes in forest cover and wetlands is best undertaken by comparing remote-sensing images (photos) taken from air planes or satellites at regular time intervals. However, these methods require funds and specially skilled staff, which are not locally available in the protected areas.

Taking ground-based photos ('Photo Documentation'), on the other hand, is rather simple and inexpensive. It provides permanent documentation which does not depend on identification skills. This method is suited to monitor habitats and land-uses. It can tell if the size of important habitats is declining, and why. Photos can be taken of the exact areas where changes are likely to occur. Photos are very useful when presenting and discussing the results of biodiversity monitoring, as most people will be convinced by photographic documentation.



Photos can be used for discussion as well as demonstration and education purposes.

EQUIPMENT

The following equipment is needed: SLR camera with battery, film, compass, pencil, Photo Documentation forms and, if possible, a tripod. When installing the method you need a topographic map. A GPS, and paint or other materials for permanently marking a site, would also be very useful.

SUITABILITY

Useful in land, freshwater and marine areas, in undulating terrain such as hills, river valleys and along the shoreline of lakes, swamps and the coast.

PERSONNEL

This method should be undertaken by PA rangers, deputized forest guards and assigned BMS staff with knowledge of the basic operations of a camera.

FREQUENCY

We recommend that you take photos every quarter of a year. You may later reduce this to once every year at view-points where no changes in land-use and habitats have occurred. Typically one PA staff or volunteer assigned to patrolling will be responsible for up to 5 photo documentation sites.

LOCATION OF PHOTO DOCUMENTATION SITES

Photo Documentation sites should be established at view-points along patrol routes and trails in seriously threatened areas (view-points are places where you can see large parts of the surrounding landscape from - not just the nearest few trees). In addition, a few sites should be established in areas without human use.

STEPS IN SELECTING AND ESTABLISHING PHOTO DOCUMENTATION SITES

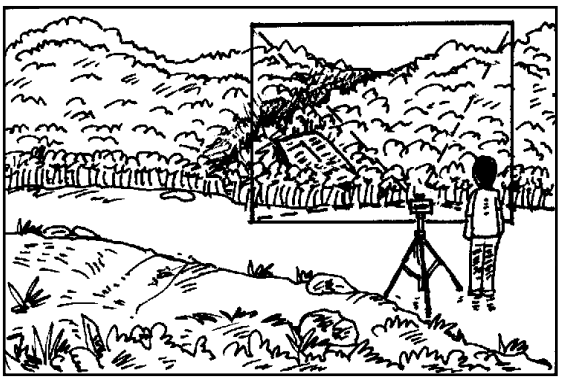
1 Get hold of a topographical map and, if possible, vegetation/forest cover and land-use maps for the protected area.

2 Identify the most seriously threatened areas on the map (e.g., where logging, swiddening or other disturbance may occur or recently occurred).

3 Draw those patrol routes and trails on the map that pass through the seriously threatened areas.

4 Mark view-points in seriously threatened areas along the patrol routes and trails as possible photo documentation sites.

5 Select up to five of those view-points. Choose those which are accessible and from where you can overlook areas of forest where logging or kaingin may occur within the next half year, or where disturbance recently occurred. Make sure you know the agreed land use for the area.



6 Go to the selected view-points and bring camera, compass, data sheet for establishment of photo documentation sites, topographic map, and if possible a GPS, paint or other tool for permanent marking of the site, and tripod.

7 Read the position and altitude using a GPS (and preferably an altimeter), and note the reading in the data sheet. If a GPS is not available, mark the approximate location of the site on your topographic map.

8 Use your compass to take a degree reading of the direction (camera angle) for each photo, and note the reading on the data sheet.

9 Take two identical photos for each camera angle.

10 Enter all the relevant information in your data sheet for the establishment of a photo documentation site (Box 10-1 and 10-2). Very careful notes must be taken during establishment of photo sites.

11 Mark the exact site of the camera location with a permanent marker so that you or your colleagues can easily find the place again (e.g. paint on big stone or rock, not on grass or loose soils).

12 Draw the location of all your photo documentation sites on a topographic map.

HOW TO TAKE A PHOTO FOR PHOTO DOCUMENTATION

1 Adjust the time (shutter speed) on the camera to 125 (1/125 of a second),

2 Look at what you want to photograph, not the sky above, through the camera. Use a tripod if available.

3 Adjust the aperture (lens opening) until the camera (light meter) indicates that the combination of shutter speed and aperture gives the correct amount of light to the film.

4 Take two photos of the same view.

5 Enter all the relevant information in your data sheet for photo documentation (Box 10-3).

6 Get the film developed and prints made. Prompt processing of used films avoids color changes associated with long storage.

7 Make sure to note reference numbers that connect data sheet, negative film and prints.

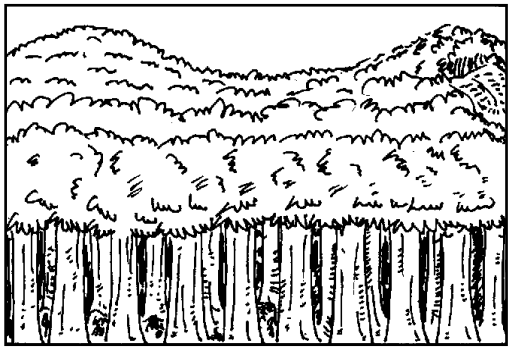
DATA STORAGE AND MANAGEMENT

Avoid touching the negatives with your fingers. Each photo must be numbered/catalogued according to the sequence of frames on the negative film. Make sure never to store any negative or print without marking them with a name and date. It should be easy to relate each photograph to the data sheet that holds full information about it.

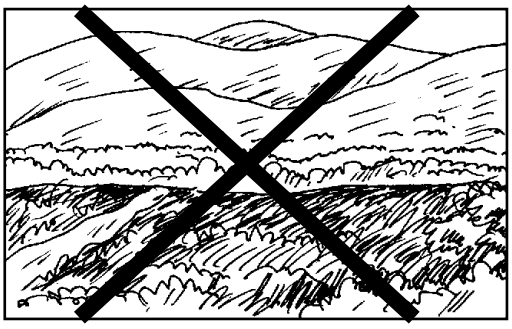
Always keep negatives and prints in a safe, dry place.

What is a good view for photo documentation?

You have to take photos where you can see the landscape but can still distinguish many single trees in your photos.



Do not take photos where you can see less than 100-500 trees. You are too close.



Do not take photos of landscapes where the forest is so far away that you cannot distinguish single trees.

Box 10-1. Filling in data sheet 1 when establishing a Photo Documentation site

In the data sheets for establishment of a Photo Documentation site you will have to write:

Data Sheet 1:

- Location and how to get to the site: Municipality, barangay, sitio and a full description identifying the site and how to get there (remember, you or somebody else, have to be able to return to exactly the same spot to take photographs).
- Position: Geographical co-ordinates. Indicate if GPS was used or if co-ordinates were estimated using topographic map.
- Your full name.
- Date of establishment.
- Number of photo angles used at the site.
- Sketch map of camera location and camera angles.

DATA SHEET 1 Establishment of Photo Documentation Site

Location (province, municipality, barangay, sitio) : ISABELA, DIVILACAN, DIMASALANGAN

How to get to the site: A 2½ hrs. BANCA RIDE FROM BALANAN GOING NORTH. AFTER REACHING DIMASALANGAN POINT, OUTER, DIMASALANSAN COVE. THERE IS THIS HIGH GRANITE ROCK 25 MW OF DIMASALANGAN POINT AT HIGH TIDE. TRIPOD LOCATION MARKED WITH WHITE PAINT.

Position (coordinates):

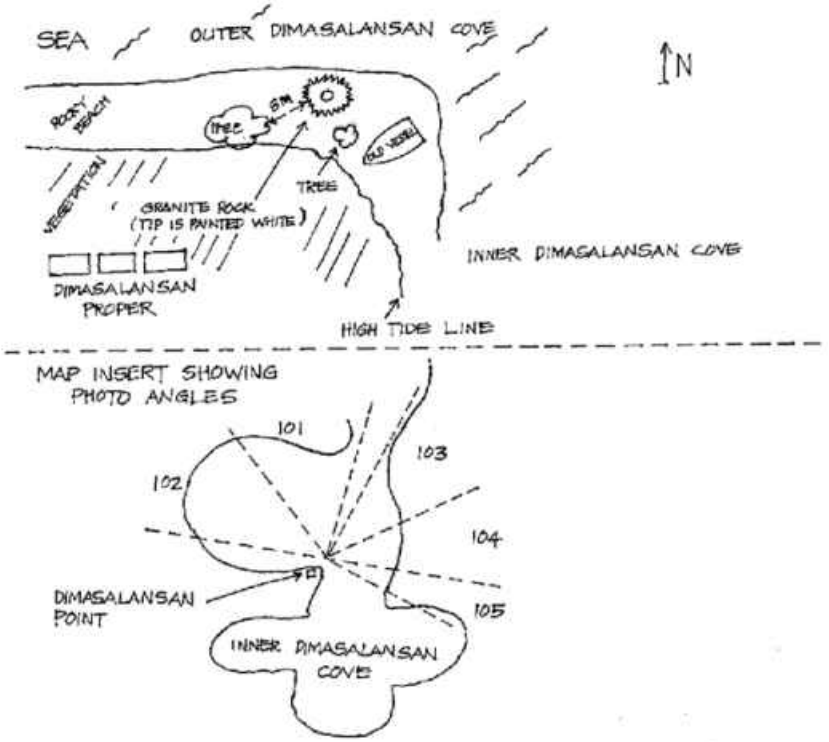
Position read from GPS or topographic map: 17°18'.790"N ; 122°23'.748"E

Your full name: PEDRO REYES

Date of establishment: 03 APRIL 1997

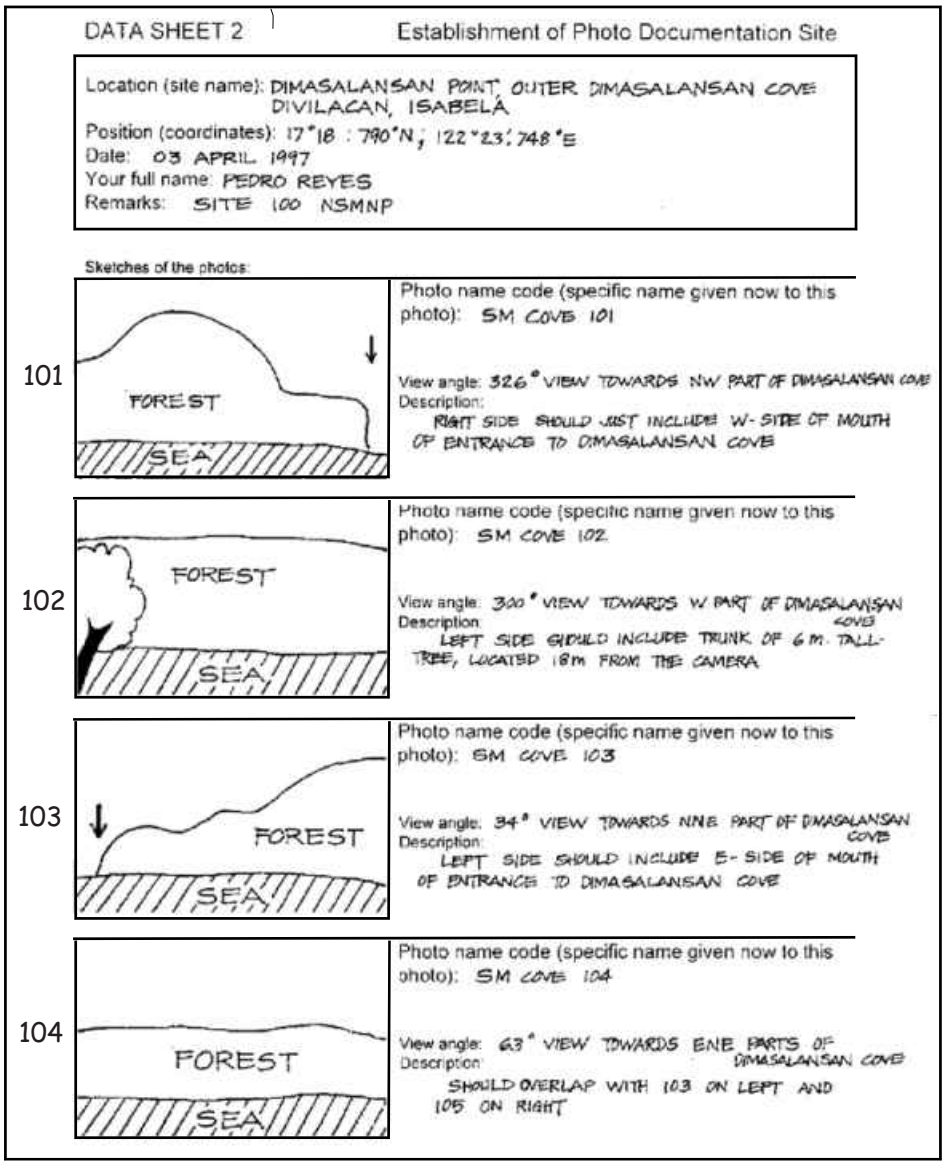
Number of photo angles used at this site: 5 (FIVE)

Sketch map of camera location (use the rest of the page to draw a map on):



Box 10-2. Filling in data sheet 2 when establishing a Photo Documentation site

In the data sheets for establishment of a Photo Documentation site you will have to write:



DATA SHEET 2 Establishment of Photo Documentation Site

Location (site name): DIMASALANSAN POINT, OUTER DIMASALANSAN COVE
DIVILACAN, ISABELA
Position (coordinates): 17°18 : 790"N; 122°23'748"E
Date: 03 APRIL 1997
Your full name: PEDRO REYES
Remarks: SITE 100 NSMNP

Sketches of the photos:

101

Photo name code (specific name given now to this photo): SM COVE 101

View angle: 326° VIEW TOWARDS NW PART OF DIMASALANSAN COVE
Description:
RIGHT SIDE SHOULD JUST INCLUDE W-SIDE OF MOUTH OF ENTRANCE TO DIMASALANSAN COVE

102

Photo name code (specific name given now to this photo): SM COVE 102

View angle: 300° VIEW TOWARDS W PART OF DIMASALANSAN COVE
Description:
LEFT SIDE SHOULD INCLUDE TRUNK OF 6 M. TALL-TREE, LOCATED 18m FROM THE CAMERA

103

Photo name code (specific name given now to this photo): SM COVE 103

View angle: 34° VIEW TOWARDS NNE PART OF DIMASALANSAN COVE
Description:
LEFT SIDE SHOULD INCLUDE E-SIDE OF MOUTH OF ENTRANCE TO DIMASALANSAN COVE

104

Photo name code (specific name given now to this photo): SM COVE 104

View angle: 63° VIEW TOWARDS ENE PARTS OF DIMASALANSAN COVE
Description:
SHOULD OVERLAP WITH 103 ON LEFT AND 105 ON RIGHT

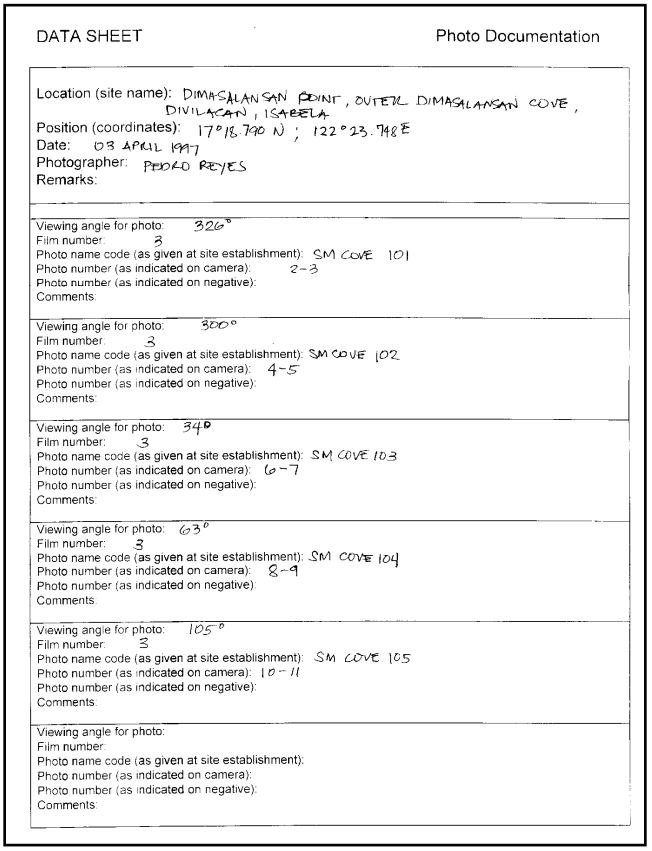
Data Sheet 2:

- Remarks: There might be signs of human activities in the area or other aspects you would like to remember.
- View angle (for each photo)
- Description of what is on the photo (for each photo)

Box 10-3. Filling in
data sheet 'Photo Documentation'

In the data sheet on Photo Documentation you must write:

- Location: the same name as used when the site was established.
- Position.
- Date and (optional) time and weather.
- Photographer: write your full name.
- Remarks: there might be signs of human activities in the area or other aspects you would like to remember.
- Viewing angle for photo.
- Film number: a specific film number which can include letters has to be written on each roll of film. This number must also be noted on the developed film.
- Photo name code (as given at site establishment).
- Photo number: this has first to be noted as indicated by the camera and later when the film is developed, the number which is actually written on the film strip along the photograph has to be noted.



DATA SHEET — Photo Documentation

Location (site name): DIMASALANSAN POINT, OUTER DIMASALANSAN COVE, DIVILACAN, ISABELA
Position (coordinates): 17°18.790 N ; 122°23.748 E
Date: 03 APRIL 1997
Photographer: PEDRO REYES
Remarks:

Viewing angle for photo: 326°
Film number: 3
Photo name code (as given at site establishment): SM COVE 101
Photo number (as indicated on camera): 2-3
Photo number (as indicated on negative):
Comments:

Viewing angle for photo: 300°
Film number: 3
Photo name code (as given at site establishment): SM COVE 102
Photo number (as indicated on camera): 4-5
Photo number (as indicated on negative):
Comments:

Viewing angle for photo: 340°
Film number: 3
Photo name code (as given at site establishment): SM COVE 103
Photo number (as indicated on camera): 6-7
Photo number (as indicated on negative):
Comments:

Viewing angle for photo: 63°
Film number: 3
Photo name code (as given at site establishment): SM COVE 104
Photo number (as indicated on camera): 8-9
Photo number (as indicated on negative):
Comments:

Viewing angle for photo: 105°
Film number: 3
Photo name code (as given at site establishment): SM COVE 105
Photo number (as indicated on camera): 10-11
Photo number (as indicated on negative):
Comments:

Viewing angle for photo:
Film number:
Photo name code (as given at site establishment):
Photo number (as indicated on camera):
Photo number (as indicated on negative):
Comments:

TIPS

1 Take photos when the light is good such as in the morning or in the early evening.

2 Do not take photos when the sun is behind what you want to photograph, otherwise you will get only a silhouette on the horizon.

3 Use a 100 or 200 ASA color print film and a readily available film brand, e.g., Kodak or Fuji. Stick to only one film brand and one photo processing shop to ensure consistent quality of your pictures.

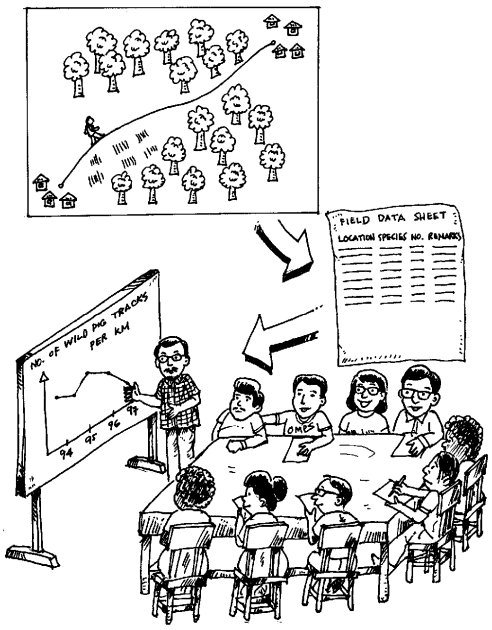
4 If your camera has a zoom lens, use the same enlargement every quarter.

5 Ground-based photos are also useful for ground-truthing of remote sensing images.

11. Transect Walk Method

This section describes the transect method for walking on foot. The method can also be used with a boat sailing along rivers and shorelines (Transect Cruise, Annex 6). Transect swimming over coral reefs and seagrass beds is described in section 12.

The Transect Walk is somewhat similar to routine patrolling using the Field Diary. However, transects are permanent, demarcated routes where there are precise recommendations as to where to walk, when to walk and what to note, etc. The recommendations aim to ensure that new and earlier data sets are comparable (Box 11-1).



EQUIPMENT

The following materials are needed: Binoculars, watch, identification guide, Transect data sheet, pencil, drinking water, and snacks. When establishing the Transect Walk route, you will also need: A topographic map, compass, a long string (50 or 100m), permanent marker (paint), a bolo, and if possible a GPS.

SUITABILITY

Useful in land areas and in drier sections of freshwater and marine areas (such as inter-tidal areas, open lake shores and wetland meadows). In areas where it is impossible to walk, you can use a boat (Annex 6). The method is not suitable in very small PAs (less than 10 ha).

PERSONNEL

This method can best be undertaken by assigned BMS protected area staff with skills in identifying species. It can also be undertaken by regular patrolling staff with the same skills. Each transect route should be surveyed by the same person every quarter. The person coordinating the conduct of Transect Walks in the protected area should also remain the same if at all possible

FREQUENCY

Each Transect Walk route should be walked once every quarter within a defined two-week period. Typically one PA staff will be responsible for 3-5 Transect Walk routes.

LOCATION OF TRANSECT ROUTES

Transect routes should be established in the most seriously threatened areas of the PA, and in the areas most important for conservation and resource use by local people. It is advisable only to establish Transect routes where the species you need to monitor are present. Transect routes are best located along patrol routes in old growth (or old secondary) forest. Some routes should pass through areas with human use, others through areas with no or minimal human use.

Box 11-1. Transect Walks: Do them the same way every time!

The Transect Walk survey has to be carried out in the same way every time:

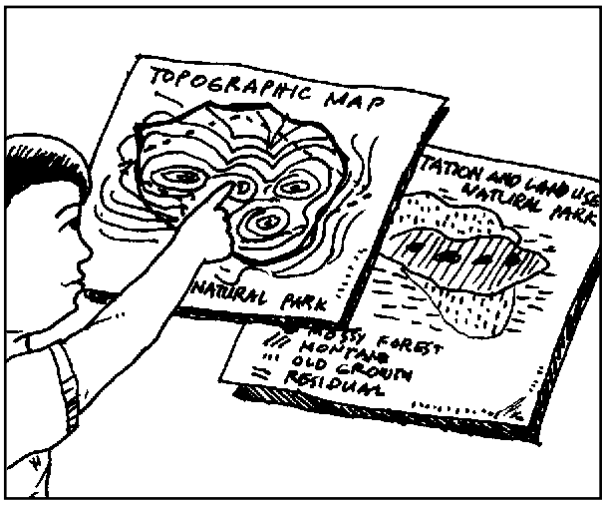
1. the same amount of time to walk (1 km per hour)
2. the same number of kilometres (2-3 kms) on
3. the same routes in
4. the same weather (if possible) at
5. the same time of the day (beginning between 6 and 7 a.m.) at
6. the same time of the year recording
7. the same species and uses in
8. the same way by
9. the same observer (or another with same identification skills, if at all possible) and using
10. the same way to estimate numbers.

Why are such rules needed?

1. Imagine what would happen if you tried to compare morning transects with midday transects: Most animals (and people) show little activity at midday. Midday data would show a false decline in biodiversity and human activity.
2. Imagine what would happen if you tried to compare data collected by an experienced and a less experienced observer: A less experienced observer would record less and the data might show a false decline in biodiversitv and resource use.

STEPS

SELECTION OF TRANSECT WALK ROUTES



1 Get hold of a topographical map and, if possible, vegetation and land-use maps for the particular area.

2 Draw patrol routes and trails on the map.

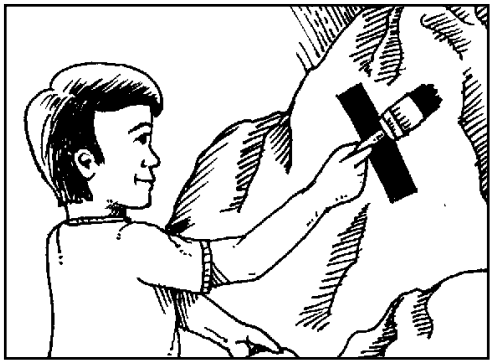
3 Are any patrolling routes passing through primary (old growth) forest? If so, they might be useful for transect surveys. Select several routes of 2-3 kilometres in different parts of the PA (preferably at different altitudes) and passing through primary (old growth) or good secondary forest. Use a small trail through closed forest (not a road with edge habitats). Avoid open areas with tall grass or bushes, and areas which are not safe to travel in when you are alone.

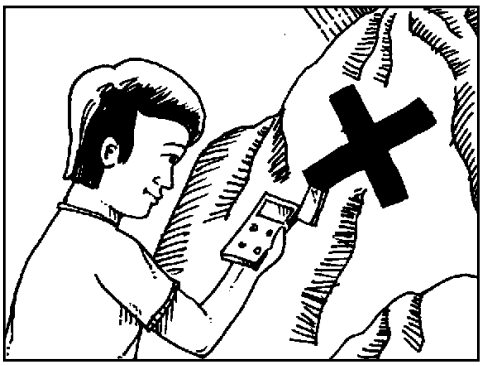
4 Do a reconnaissance of the proposed routes to check that they are possible to walk (e.g. not too steep) and that they are located inside the PA.

ESTABLISHMENT OF TRANSECT WALK ROUTES

1 Visit the proposed routes. Make sure that a 2-3 kilometres transect route can be established on each patrol route so that it passes through primary forest or old secondary forest within priority areas for conservation. If not, another site has to be selected.

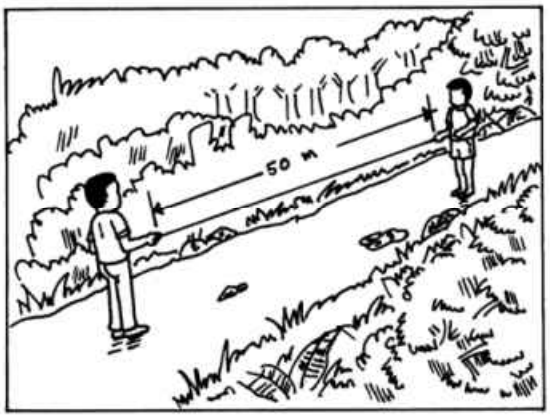
2 For each selected transect route, mark the starting point of the transect with a permanent marker (e.g. paint on rock, big stone or tree, not on grass or loose soils).





3 Use a GPS to obtain the geographical co-ordinates for the transect starting point.

4 Use a GPS (or an altimeter) to obtain the altitude for the transect starting point.



5 From the starting point, measure (using the string) and mark (using paint) every 250 m (5 × 50m) distance to the end of the route.

6 Note habitats (e.g. lowland forest) within each 250 m section and the condition of the forest (e.g. primary forest, logged forest, forest with kaingin, secondary growth forest, scrub, grassland, or cultivated area). Such broad categories must be noted even if a more precise description is also given.

7 Mark the end point of the transect with a permanent marker. The transect should be at least 2 kilometres and not more than 3 kilometres and it should end at a 250 meter mark.

8 Use a GPS, if available, to obtain the geographical co-ordinates for the transect end point.

9 Use a GPS (or an altimeter), if available, to obtain the altitude for the transect end point.

10 Sketch maps of routes must be prepared as well as precise descriptions of where the end points of transects are. The transect routes must also be plotted into topographic maps of 1:50,000 scale or more detailed.

11 Data to be noted when establishing a Transect Walk route is listed in Box 11-2.

Box 11-2. Data to be noted when establishing a Transect Walk route.

- Name given to the transect (e.g., name of nearest sitio, mountain or river system)
- Transect location (province, municipality, barangay, sitio)
- Geographical co-ordinates for starting point and end point and land marks along the route.
- Altitude for starting point and end point.

- Total length of transect (meters).
- Major habitat type and modification level for each 250 meters section.
- Date of establishment

- Full name
- Plot the location of the route on a topographic map.

WHEN WALKING THE TRANSECT

1 You must walk the Transect Walk route with a constant rather slow speed. The distance between two 250 meter markers has to be walked in precisely 15 minutes (that is one kilometre covered every hour). Only short stops are permitted when identifying and noting. Otherwise the survey should not be disrupted, not even if illegal activities are observed. If a Transect Walk is disrupted, it should be undertaken again a few days later.

2 You must always begin Transect Walks between 6 and 7 am and finish before 11 am.

3 You should walk the transect alone. Different observers have different identification skills and different estimates of numbers. A less experienced observer records less and data will show a false decline in biodiversity and resource use. Be as quiet as possible so as not to scare away wildlife.

4 Try to keep track of individuals or the flocks of wildlife species. If there are many individuals or flocks of a species there is a risk of double counting because of confusion from animals appearing in all directions. Species that move quietly between places where they sing or call might also cause confusion.

DATA STORAGE AND MANAGEMENT

After each Transect Walk, the observations written in the Transect Walk data sheet must be tallied by the BMS observer. The filled out form should be turned over to the BMS Coordinator and filed in a ring-binder and stored in the BMS filing system at the Protected Area Office. A copy should be submitted to the PENRO for safe storage.

TIPS

1 Use a good quality pencil of medium point, no. 2 or 3. Never use ball-point pen as this ink tend to fade or run when wet.

2 Always store field notes/data sheets in a waterproof container such as a plastic bag.

3 Make sure to bring water and snacks with you on the Transect Walk.

4 Don't walk transects in heavy rain or typhoons. However, be prepared for a few drops of rain. It is time to cancel the walk when there is so much rain that you cannot use your binoculars.

6 When you survey the transect route wear clothes with dark colors. Do not wear white or bright colored clothes since this would scare away wildlife.

7 It is difficult to estimate numbers in groups of Long-tailed Macaque (Unggoy). When you encounter this species, write your best estimate of the group size as well as the minimum and maximum number. Example: Unggoy 4 (min. 3, max. 5)

FIELD DATA SHEET FOR TRANSECT WALK

Observer: PEDRO REYES

Location: THE FOREST TRANSECT ON THE TRAIL FROM X TO Y

Length of transect: 3 Km.

Date: OCT. 13, 1997

Starting time (must be between 6.00 and 7.00) 6:01 am

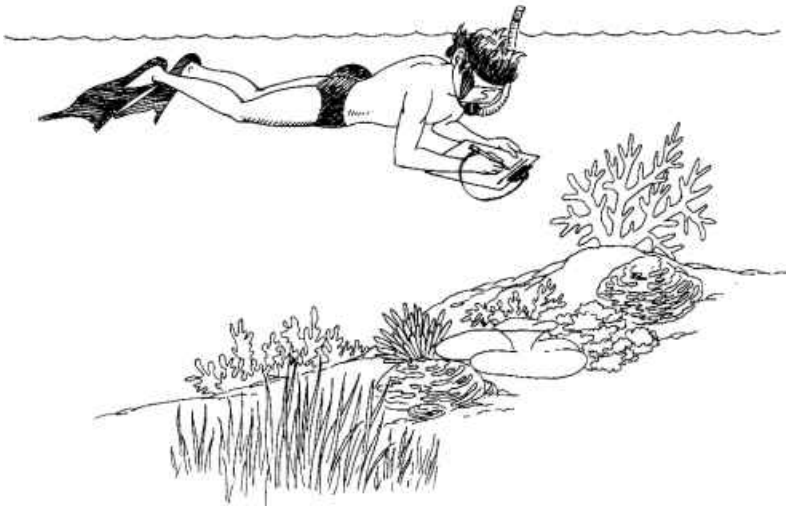
Comments (e.g. on weather): NO WIND OR RAIN

Species/use recorded	Number	Time (or distance from transect start)	Remarks on what was recorded
PHIL. DEER	1	6:10	TRACKS (one or two individuals)
PIGEON	3	6:15	I COULD SEE THEM UP IN THE CANOPY PERHAPS THERE WERE MORE.
TARICTIC HORNBILL	1	6:25	HEARD
RED JUNGLEFOWL	1	6:30	HEARD, PERHAPS FROM THE VILLAGE
PERSON	2	6:40	TOURISTS WITH BINOCULARS, PERHAPS FROM AMERICA.
CHAIN SAW	1	6:55	HEARD FAR AWAY. PERHAPS FROM OUTSIDE THE P.A.
PHIL. PIG	5	7:20	MANY TRACKS. I ESTIMATE 5 INDIVID
PIGEON	1	7:30	HEARD
STUMPS	10	7:50	THE SAME NO. I COUNTED HERE LAST TIME (JULY)
TARICTIC HORNBILL	1	7:51	PERCHING. MALE.
REDJUNGLEFOWL	1	7:58	HEARD.

Figure 11-1. Example of a filled in Field Data Sheet for a Transect Walk

12. Transect Swim Method

This method is an adaptation of the Transect Walk method to marine areas. The method records changes in priority marine organisms, resource uses and threats. It entails swimming over the top of seagrass beds and coral reef in predetermined survey routes with the use of skin diving equipment (i.e. mask, snorkel and rubberized fins). Local communities and volunteers assigned to the BMS could use their wooden goggles and wooden fin.



EQUIPMENT

The following materials are needed: mask, snorkel and fins, plastic writing slate or plastic laminated Transect data sheets, pencil, identification guide, waterproof watch and compass. It is also recommended to have drinking water and snacks. When establishing the Transect Swim route, you will also need cement, a long string (25m), a map of the area, and, if possible, a GPS.

SUITABILITY

Useful in marine areas with shallow (less than 20 feet of water depth) coral reefs and seagrass beds in areas of good visibility.

PERSONNEL

This method should be undertaken by regular BMS staff able to swim and to identify marine habitats and organisms. It can also include volunteer coastal indigenous people and other community members with vested interest in maintaining marine resources. Each transect route must be surveyed by the same BMS observer every time.

FREQUENCY

Each survey path should be surveyed once every quarter within a defined two-week period. Two of the surveys should be during the inter-monsoon seasons (May and October).

LOCATION OF TRANSECT SWIM ROUTES

Transect Swim routes should be located along patrol routes near shallow coral reefs or seagrass beds that are particularly threatened or important for protected area communities and for conservation.

STEPS

SELECTION OF TRANSECT SWIM ROUTES

1 Obtain a map of the area.

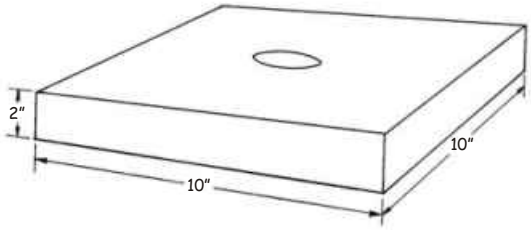
2 Draw the patrol routes on the map. Are any patrol routes near coral reefs or seagrass beds which are particularly threatened or important for protected area communities and for conservation? If so, a route from the seagrass bed to the shallow (i.e. 15-20 feet) portions of the coral reef might be useful for a Transect Swim. Select several transect routes of 100-500 meters.

3 Photocopy and/or enlarge the map of the transect routes to the desired useful scale. For example: 1:50,000 scale enlarged 5× gives 1:10,000.

4 Locate and mark the preferred transect routes on the map.

ESTABLISHMENT OF TRANSECT SWIM ROUTE

1 Visit the selected sites. Make sure that a route of at least 100 meter can be established. If not, another site has to be selected. If the area with seagrass bed and coral reef is large and the observer is a good swimmer, the route can be extended to 500 meter.



Permanent marker of cement

2 For each selected Transect Swim route, establish permanent markers of cement at the sea bed at the start and end points and for every 25 meter. In addition, if the route is parallel to the shore mark the tree (or cliff, or other land mark) found on the beach opposite the start and end points of the route.

3 Write down the major seabed habitat type for each 25 meters section. Major seabed habitat types are: seagrass bed, live coral, dead coral, mud/sand, rock. Rock is stones larger than finger-size.

4 If you have a boat and a GPS, obtain the geographical co-ordinates for the start and end points.

WHEN SWIMMING THE TRANSECT

1 You must always begin Transect Swims at the same time of the day, preferably at 9 am.

2 From the start point, swim along the survey route for 5 minutes. Maximum speed of swim should be only 25 meters every 5 minutes. This slow speed will enable you to see a lot.

3 Record the priority marine organisms you observe. For example, commercial fish larger than an outstretched hand, butterfly fish, sea cucumbers, urchins, crown-of-thorn starfish, giant clams.

4 Take note of any signs of resource uses and threats you observe. For example, presence of blasted or bleached corals, siltation, crown-of-thorn starfish infestation, visible man-made pollution, land plant debris, oily film on the water, broken corals etc.

5 Every 5 minutes, pause, and record all observations on the plastic laminated Transect data sheet (Figure 12-1). Relax for 1-2 minutes.

6 Repeat steps 2-5 until the entire route has been surveyed.

7 Add other notes (e.g., recent storms, nearby developments, signs of fishing, visibility in water reduced by sedimentation, etc.).

8 Transcribe the data onto a Transect data sheet which is not laminated.

DATA STORAGE AND MANAGEMENT

The filled out data sheet should be turned over to the BMS Coordinator and filed in a ring-binder in the BMS archive at the Protected Area Office. A copy should be submitted to the PENRO for safe storage.

TIPS

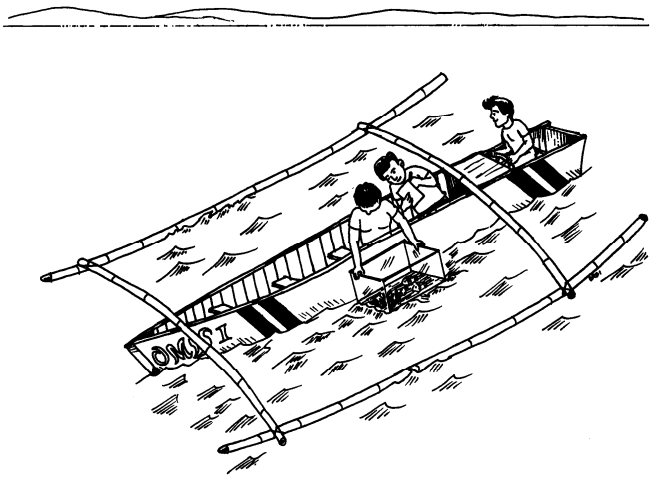
1 Be careful when you estimate size underwater. Everything appears larger and closer than it actually is.

2 If you do not have a plastic writing slate, take a blank Transect data sheet (Annex 7), photocopy it, place it back to back and laminate it in plastic. Roughen the plastic surfaces with fine sandpaper. Now it can be written upon underwater with a pencil.

3 If you are not familiar with using a mask, snorkel and fins, you can observe the sea bed from a boat with a glass bottom box (60 x 60 x 40 cm) instead.

   The box should be tied to the side of the boat allowing its top to float on the water.

   When surveying the transect, you should stop every 3 minutes and record your observations. The speed should be 50 meters every 3 minutes equivalent to a slow walk.



Use of a glass bottom box instead of mask and snorkel

FIELD DATA SHEET FOR TRANSECT

Observer: FILEMON T AMBASAKAN

Location (site name): NAGBALAYANG TO MAUGAN, BASCO BAY

Length of transect: 200M

Date: 8 MAY 2000

Starting time (TW between 6 and 7 am. TS between 9 am and 3 pm): 9:00

Comments (e.g. on weather): VISIBILITY IN WATER EXCELLENT

Species/use recorded	Number	Time (or distance from transect start)	Remarks on what was recorded
		9:00 - 9:05	
FISH TRAP	2		FOR REEF FISH
ANCHOR	1		
BUTTERFLY FISH	6		
SEA CUCUMBER	2		
		9:08 - 9:13	SOME SEDIMENT IN WATER
BLASTED CORAL	2		BLASTED LONG TIME AGO (PERHAPS LAST YEAR)
GLASS BOTTLE	1		
URCHIN	14		

Figure 12-1. Example of a filled in Field Data Sheet for a Transect Swim

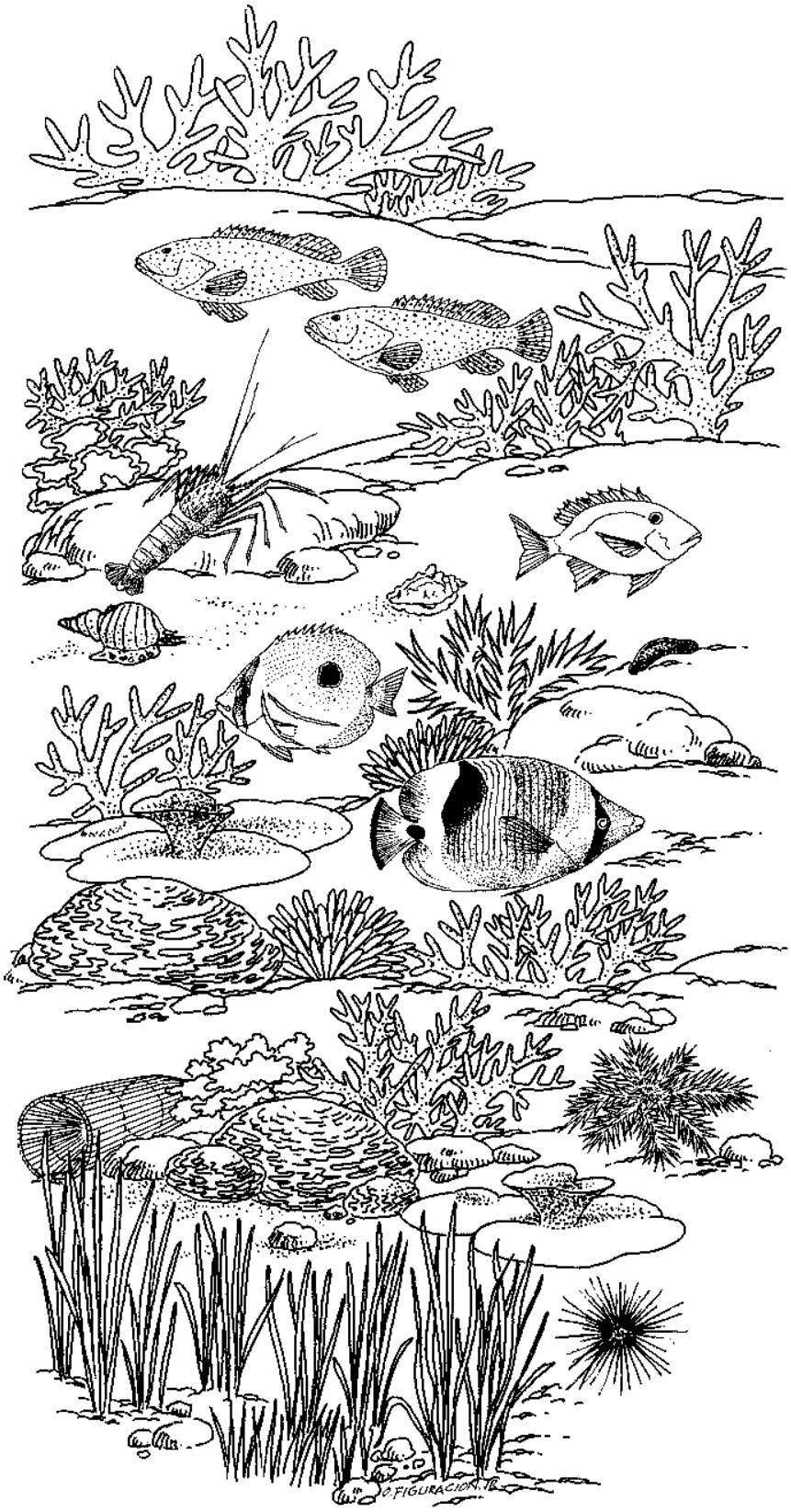


Figure 12-2. Sample picture of Transect Swim route

13. Which resource uses and which species should you monitor?

Biodiversity in Philippine protected areas encompasses thousands of life-forms, many of them not even named and described. It is impossible to monitor all of these.

The biodiversity of a protected area will remain almost the same as long as no large-scale habitat changes take place. If habitat changes do take place, these will probably be the result of human activity. It is therefore reasonable to focus biodiversity monitoring mainly on key habitats and uses in a protected area. It is very unlikely that wildlife species would become extirpated without major human activity followed by habitat changes.

STEPS

1 Look at the list of suggested signs of resource uses and species to monitor (Box 13-1 and 13-2).

These 'indicators' of resource use and biodiversity have been selected based largely on the following criteria for usefulness and practicality:

- those which reveal trends (changes) in resource use and biodiversity;
- those which are easy and cost-effective to collect data on, analyze and report on;
- those which are meaningful to local people;
- those which provide for continuous assessment over a wide range of disturbance levels.

There are species which are more sensitive or more threatened than those selected. None of these, however, is easily identified. Results based on trends of species which are difficult to identify are likely to reflect the identification skills of the observer rather than a change in biodiversity.

2 Identify which of the resources uses and species in Box 13-1 and 13-2 are likely to occur in your area. We recommend that you monitor those.

3 Are there other signs of resource uses or other species, which in your opinion are equally useful and practical to monitor? Then you may consider adding these to your list.

You can add as many signs of resource uses and species as you like, but we suggest for simplicity that you do not add more than a total of 5 extra resource uses and species to your list in the first years. Discuss your selection of indicator resource uses and species with the PASu or CENRO in charge, the PAMB and other knowledgeable persons, including representatives of indigenous people and other local communities.

Make sure the list includes representative resource uses and some of those species that are of high importance for use by the local communities.

4 Now agree with the PASu or CENRO in charge on the list of signs of resource uses and species to be monitored in your area.

Box 13-1. Forest areas: Suggested species and signs of resource uses to monitor (a list to select from)

English name	Scientific name	Tagalog name	Indicator for
BUTTERFLY			
Merry Widow	*Atrophaneura semperi*		f
Pretty Baby	*Pachliopta* spp.		f
Rhapsody	*Achillides daedalus*		f
Kirirai	*Lamproptera meges/L. curius*		f
BIRDS			
Philippine Eagle	*Pithecophaga jefferyi*	Aguila, Manaol, Mamboogook	f, H
Rufous Hornbill	*Buceros hydrocorax*	Kalaw	f
Tarictic Hornbill	*Penelopides* spp.	Tariktik	f
Red Junglefowl	*Gallus gallus*	Labuyo, Manok ihalas	f, H
Pigeons and doves[1)]	Columbidae	Kalapati	f, H
Bleeding-heart Pigeon	*Gallicolumba* spp.	Lagbaan, Puñalada	f, H
Philippine Eagle-Owl	*Bubo philippensis*	Kuwago	f
MAMMALS			
Long-tailed Macaque	*Macaca fascicularis*	Unggoy	f, H
Philippine Warty Pig	*Sus philippensis*	Baboy-damo, Baboy-ihalas	f, H
Philippine Brown Deer	*Cervus mariannus*	Usa, Binaw	f, H
Large flying foxes	*Acerodon jubatus/ Pteropus vampyrus*	Bayakan, Kabog	f, cfo, H
SIGNS OF RESOURCE USES			
Stump		Stump	L
Piece of timber		Tablon	L
Sound of chainsaw		Tunog ng chainsaw	L
Charcoal stove in use		Lutuan sa uling na ginagamit	L
Forest products, e.g. on market		Produktong galing sa kagubatan, halimbawai sa palengke	U
Fishing gear and traps		Gamit at bitag sa pangingisda	F
River water availability/quality		Packakaroon ng tubig sa ilog/kalidad	L
Person (and activity)		Tao (lahathang ginagawa)	U

LEGEND FOR INDICATOR COLUMN:

HABITATS:

f	forest habitat
cfo	coastal forest habitat
m	marine habitat
w	fresh/brackish water habitat

HUMAN ACTIVITY:

B	by-catch
D	destructive fishing method
E	egg collecting
F	fishing and harvest of shellfish/sea cucumbers
H	hunting
L	logging
U	resource use
O	outsiders harvest resources

(1) Experienced observers may be able to distinguish between different pigeons and doves

Box 13-2 Freshwater and marine areas: Suggested species and signs of resource uses to monitor (a list to select from). Legend on page 37.

English name	Scientific name	Tagalog name	Indicator for
SPECIES BELOW WATER			
Sea cucumber	Holothuroidea	Balatan	m, F
Urchin	Echinoidea	Tuyum	m
Crown-of-thorn starfish	*Acanthaster planci*		m
Shark	Selachimorpha	Pating	m, F, D
Commercial fish (1)	Several families	Isdang pambenta	m, F
Butterfly fish	Chaetodontidae	Paro-parong dagat	m, F
Sea horse	*Hippocampus* spp.		m, F
Squid/octopus	Cephalopoda	Pusit/Pugita	m, F
Giant Clam	*Tridacna* sp.	Taklobo/Manglet/ Basa	m, F
Window Pane Shell	*Placuna placenta*	Kapis	m, F
Smooth Top Shell	*Trochus niloticus*	Samong	m, F
Turban Shell	*Turbo crassus*	Buteng	m, F
Giant Triton	*Charonia tritonis*	Tambuli	m, F
Lobster	Astacidea	Banagan	m, F
OTHER SPECIES			
Coconut Crab	*Birgus latro*		m, F
Marine turtle	Chelonidae	Pawikan	m, B, E, H
Crocodile	*Crocodylus* spp.	Buwaya	m, w, H
Seabird breeding colony		Pugaran ng mga ibong pandagat	m, E
Duck	Anatidae	Pato	w, H
Large heron-like bird	Ardeidae, large species	Malaking tagak	m, w, H
Small heron-like bird	Ardeidae, small species	Maliit na tagak	m, w, H
Wader	Charadriiformes		m, w, H
Other waterbird			m, w, H
Philippine Scrubfowl	*Megapodius cumingii*	Okong	cfo, E
Dugong	*Dugong dugon*	Dugong/Duyong	m, H
Small-Clawed Otter	*Amblonyx cinerea*	Dingguin	m, w, H
Dolphin/whale	Cetacea	Lumba-lumba/Balyena	m, B
SIGNS OF RESOURCE USES			
Fish and wetland products, e.g. on market		Isda at produktong mula sa basang-lupa, halimbawa sa palengke	F, U
Dunghill and new garden decoration of shells		Kabibing palamuti sa hardin	F
Large number of dead fish or other animals/plants		Malaking bilang ng patay na isda o ibang hayop	D (possible)
Fishing vessels of outsiders		Lantsa ng dayuhan	O
Fishing gear and traps		Gamit at bitag sa pangingisda	F
Charcoal stove in use		Lutuan sa uling na ginagamit	L
Person in inter-tidal area		Tao sa baybayin	F
Person (and activity)		Tao (lahathang ginagawa)	U
Sound of dynamite-fishing		Tunog/putok ng nag-didinamita	D

(1) Only individuals larger than an outstretched hand

14. From field data to results: Data organisation, analysis and interpretation

You should ensure that at the first meeting of the Executive Committee of the Protected Area Management Board every quarter the results of the previous quarter's biodiversity monitoring will be on the agenda.

In due time, prior to this meeting you should look over your data and try to highlight any changes over time in resource use or abundance of species. For the Photo Documentation and Transect methods, a period of 4-6 years will normally be the minimum duration of monitoring that could yield any meaningful trends. For the Focus Group Discussion and Field Diary methods, however, even the initial monitoring activities can provide useful results.

This chapter describes the data organisation, analysis and interpretation for each of the Biodiversity Monitoring System methods.

14.1 Focus Group Discussion method.

DATA ORGANISATION:

1 Draw up a report using the formats in Annex 4, after each Focus Group Discussion. The report should comprise:
- Main issues discussed, a narrative description of the discussion of perceived changes, problems and solutions related to key resource uses and issues (Format 1),
- A matrix for resource uses (Format 2), and
- A matrix for species observed (Format 3).

The narrative description of perceived changes and problems/solutions must be made after each meeting even if the group do not perceive any changes since last time.

2 Take all the reports from the last quarters. List all the monitoring themes. Divide them into those that indicate change (in wildlife, resource use or in effectiveness of the protected area to provide benefits to local communities), and those that do not.

ANALYSIS AND INTERPRETATION:

3 Do the findings correspond to your expectations? Compare the findings with the results of monitoring in previous quarters. Have several Community Monitoring Groups reported the same problems? Are there perceived trends that are common to several Groups? If so, are the changes caused by a change in monitoring routines (for instance, when members of the Group begin farming instead of fishing, or when the composition of the Group

changes). Or could they be caused by weather or other natural background conditions? Compare with the results of other methods.

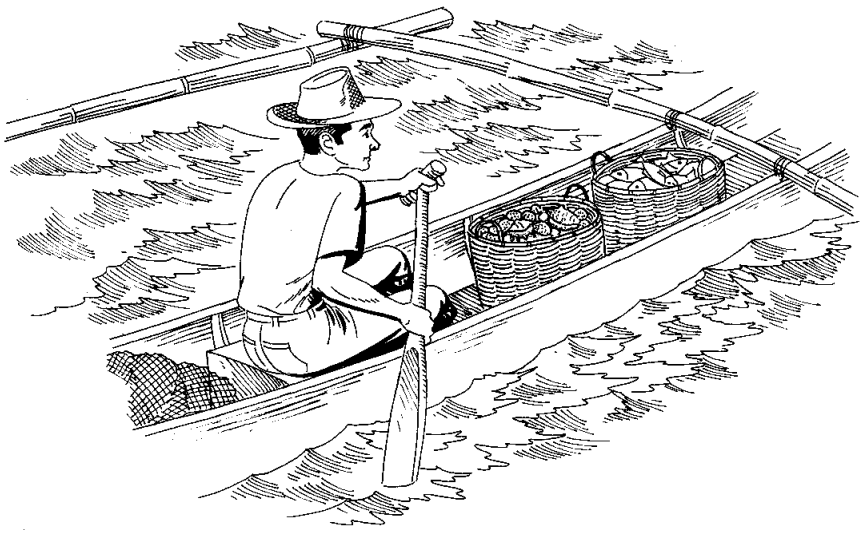
4 Are there indications of over-harvesting situations or consistent resource use problems that need to be discussed with the villagers at a community meeting?
Are there any changes that are so serious they need immediate attention from the PASu or CENRO in charge (such as big tree stumps indicating large-scale logging, or foreign fishing vessels using destructive fishing methods)?

5 If there are major changes not caused by a change in monitoring routines or natural background conditions then you should assess the reason for the change, the importance of the change and whether any management intervention is appropriate (Chapter 15). It might not be the amount of a resource harvested that has changed but perhaps the time it takes to harvest the resource, the number of people involved in harvesting a resource, or the number of dealers or middlemen.

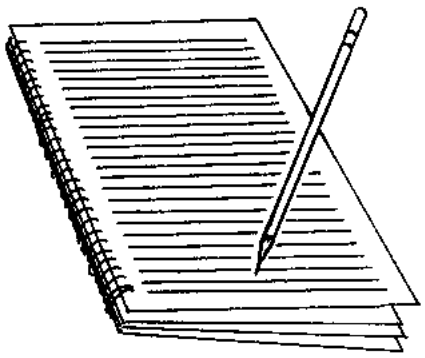
6 Present the findings to local people at community meetings and ask for their advice. Do they consider the findings relevant? Discuss possible actions to be taken by the people themselves, the Protected Area Management Board and the Local Government Units (Chapter 15).

TIPS ON MONITORING FISHERY:
When monitoring the fishery through the Focus Group Discussion method (Annex 5), take the filled-in Fishery Record Sheets and look at the catch per unit effort (CPUE) from the same seasons in the same barangays. See if any changes have occurred. Then continue with steps 3-6 above.

Fish and other freshwater and marine resources are heavily used. Sometimes the CPUE will be based on a large amount of data, making it likely that observed trends are real. The changes in CPUE are often of very significant and immediate importance to the communities. In your interpretation, look at both the reported CPUE as well as the perceived trends and problems as discussed with the Community Monitoring Groups.



14.2 Field Diary method.



DATA ORGANISATION:

1 Take your note-book (or ring-binder) with your Field Diary.

2 Arrange all resource uses and species within a certain area (ex. the protected area) and a certain time period (ex. 3 months) in alphabetical order. Example: Sitio Diclaclong; January-March 2000; Fern, Narra, Pahutan, Rattan, Wild Pig, Tambuli, etc.

ANALYSIS:

3 Calculate the number of records of each.
Example: Ferns 1+1+1=3 records, Narra flitches 1+1=2 records, Pahutan 1+1=2 records, etc.

4 Calculate the number of individuals or bundles or bunches (depends on unit used for measuring the quantity of the item).
Example: Ferns 2+3+2=7 bundles, Narra flitches 4+3=7 pieces, etc.

5 If you have a map plot those records you find particularly interesting (threats, resource uses of particular importance to local communities, threatened species, etc.).
Example: map of records of Narra flitches, Diclaclong, January-March 2000.

INTERPRETATION:

6 Are there indications of over-harvesting situations, or consistent resource use problems that need to be discussed with the villagers at a community meeting?
Are there any observations that are so serious that they need immediate attention from the PASu or CENRO in charge? Example: large number of Narra flitches, or large-scale killing of marine turtles.

7 Do the findings correspond to your expectations? Compare the results with results of monitoring in previous quarters. Are there major changes in numbers or distribution of records of resource uses and species?

8 If so, are you sure the changes are not caused by a change in patrol routines (change in sites visited, duration of time on each site, number of people talked to at each site, etc.)? Or perhaps by weather, seasons or other natural background conditions? Compare with the results of the other methods.

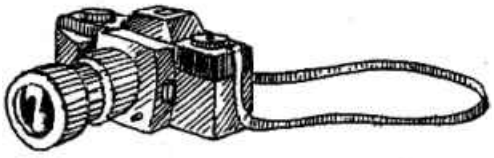
9 If there are major changes not caused by a change in patrol routines or natural background conditions, then you should assess the reason for the change, the importance of the change and whether any management intervention is appropriate (Chapter 15).

14.3 Photo Documentation method.

ORGANISATION OF THE PHOTOS:

1 Take the ringbinder or photo-album with the photos.

2 Look at all photos taken from the same view-point.



3 Begin with the oldest photo.

4 Have any changes occurred over the months?

5 Continue with photos from the other view-points.

ANALYSIS AND INTERPRETATION:

6 If there are major differences between the photos you should carefully analyse whether they are caused by a change in the natural background conditions. Perhaps the light, the cloud cover or the weather were different at the time when the photos were taken. Or maybe a difference is merely the result of the photos being taken in different seasons.

7 If there are major differences that are not caused by changes in the natural background conditions, then assess the importance of the differences. For instance, check whether the same differences occur in photos from other view-points.

8 If you consider that the differences are important, then try to identify the reason for the differences. Differences can, for example, be caused by land-slides, swiddening, logging, or forest conversion for farming or grassland, etc.

9 If differences are caused by a change in land-use or size of vegetation type blocks, you should compare this with the results of the other methods and assess whether any management intervention is appropriate (Chapter 15).

10 See whether selected photos can serve as a basis for discussing management initiatives and for demonstration purposes in meetings with the PAMB and local communities. You may also want to quantify the differences by calculating how many photos show significant differences in vegetation or land-use, or even by estimating for each photo the proportion of the photographed land that has been subject to change.

11 After having looked at the photos, return them to their ring-binder or photo-album so they will not be damaged by dust.

14.4 Transect methods.

This section describes the data organisation, analysis and interpretation of transect methods walked by foot on land (Transect Walk) and swum over coral reefs and seagrass beds (Transect Swim). If you are carrying out transects from a boat, the data organisation, analysis and interpretation follows the same procedure as described for the Transect Walk.

Transect Walk method.

DATA ORGANISATION:

1 Take your Transect Walk field data sheets.

2 For each Transect Walk, score the observations in your data sheet according to species and resource uses.

Example:

Species	Score	Sum
Deer	|	1
Pigeon	𝍸 | |	7
Persons	| |	2
Rattan gatherers	| | | |	4

ANALYSIS:

3 For each species or resource use, divide the sum by the length of your transect in kilometres. This will give you the frequency of your observations per kilometre ('relative abundance'). After a few years a graph can be made showing relative abundance of a species or resource use per quarter or per year.

Example with a transect which is 2 km long:

Species	Sum	Individuals/km
Deer	1	0.5
Pigeon	7	3.5
Persons	2	1.0
Rattan gatherers	4	2.0

INTERPRETATION:

4 Compare the results with results from the same transect in previous quarters (do not compare between different species or resource uses, or between different transect routes). Do the findings correspond with your expectations? Are there major changes in the relative abundance of any species or resource use?

5 If so, you first need to assess whether the data is sufficiently extensive.

When there is little data, differences are often caused by chance alone. For example, if you flick a coin twice and see a head both times, you cannot be sure that there is a head on both sides of the coin. If you flick the same coin five times and still see a head every time, you are more sure that both sides have a head. However, it could still happen by chance.

It is the same with the monitoring data. The more data and the clearer change (or 'trend') they show, the more you can be sure that the trend is real.

Here are some examples for you to consider:

- absence of observations of a species or resource use does not necessarily mean absence of the species/resource use (if you do not record wild pigs in your transect, it does not mean that wild pigs are extirpated in your protected area);

- a decrease in the number of observations of a species does not necessarily mean that the species is actually declining;

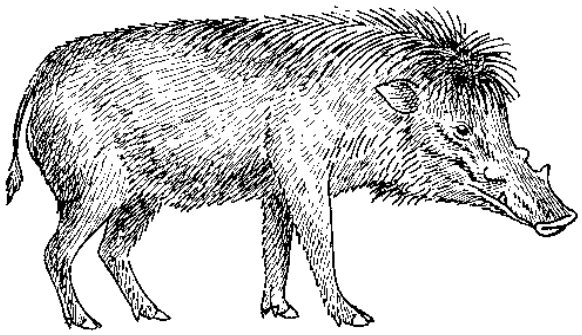
- absence of a uniform trend or pattern in your data does not imply errors in your monitoring (it could just be because you have too few records to show real trends).

6 Secondly, you must assess whether the changes could have been caused by a change in monitoring routines (timing of the Transect Walk, abilities of the observer to detect wildlife species by their sounds, etc.), or a change in staff (remember the Transect Walk should be surveyed by the same person every quarter).

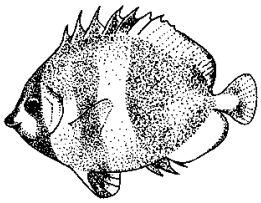
7 Thirdly, you should assess whether the changes could have been caused by seasonal or annual change in the ability to record wildlife or resource use, or by weather or other natural background conditions.

8 If there are major changes that are not caused by chance (insufficient data), or a change in monitoring routines or staff, or natural background conditions, then you should assess the reason for the change, the importance of the change and whether any management intervention is appropriate (Chapter 15).

TIPS ON WILD PIGS:
When analysing data on wild pigs based on foot prints, use "number of 250 meter transect sections with signs of pigs" instead of "number of individuals recorded" in Step 2. Step 3 will then give you "number of transect sections with signs of pigs per kilometre". Then continue with steps 4-8 above. It is difficult to estimate number of wild pigs based on foot prints. This procedure will give a more reliable estimate of the relative abundance.



Transect Swim method.



DATA ORGANISATION:

1 Take the ring-binder with the Transect Swim data sheets.

ANALYSIS:

2 For each Transect Swim, score the observations of marine organisms, signs of resource uses and threats according to species and signs.

Example:

Species/ sign of threat	Score	Sum
Butterfly fish	𝍸	6
Urchin	|	1
Crown-of-thorn starfish	|	1
Blasted coral	|||	3

INTERPRETATION:

3 Compare the results with results of monitoring in previous quarters (do not compare between different species groups, or between different sites). Do the findings correspond with your expectations? Are there major changes in the occurrence of marine organisms, or the signs of resource uses and threats?

4 If so, you first need to assess whether the data is sufficiently extensive. When there is little data, differences are often caused by chance alone. The more data and the clearer change it shows, the more you can be sure that the change is real.

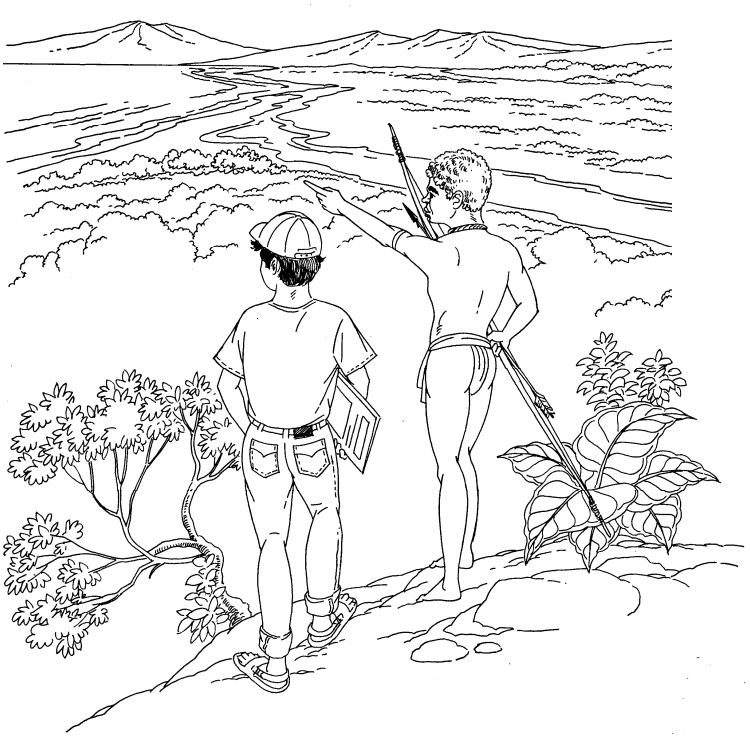
5 Secondly, you must assess whether the changes could have been caused by a change in monitoring routines (ability of the BMS observer to detect marine organisms, etc.), or a change in staff (remember transect routes should preferably be surveyed by the same person every time).

6 Thirdly, you should assess whether the changes could have been caused by change in the ability to see the marine organisms, or by weather or other natural background conditions.

7 If there are major changes that are not caused by chance (insufficient data), or a change in monitoring routines or staff, or natural background conditions, then you should assess the reason for the change, the importance of the change and whether any management intervention is appropriate (Chapter 15).

15. From results to management action

The most challenging aspect of the Biodiversity Monitoring System is that of being able to move from your results to a position of identifying appropriate management responses.



We trust that you have already ruled out the possibility that the observed change in resource use or in the abundance of a species is caused by change in monitoring efforts, weather, or seasons (or other biases).

If you consider that the change you have observed is important, it is now time to identify:

- the reason for the change, and
- whether any management intervention is appropriate.

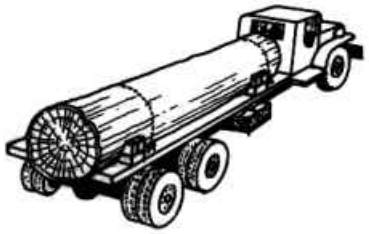
STEPS

1 Identifying the reason for the change. Since change in biodiversity in a protected area is often related to the human use of the area, you need to know what the likely impacts of different human activities are in order to identify the reason for the change. Examine the possible impacts of the human activities in your area and assess whether the change may have been caused by any of these. In addition, use information on possible reasons for change from the Focus Group Discussions and Field Diaries.

Human activities can be grouped into those that involve serious destruction of natural habitats (such as lowland forests, montane forests, marshes and coral reefs) and those that only affect single species.

Human activities that involve serious destruction of forest habitats include:

- logging using bulldozers and trucks,
- carabao logging,
- kaingin swiddening,
- agricultural development,
- industrial development,
- mining, and
- road construction.



A summary of the common impacts of these activities is provided in Box 15-1.

Box 15-1. A summary of the common impacts of logging, kaingin, agricultural development, industrial development, mining, and road construction in or adjacent to forest protected areas.

Increased access and in-migration. Increased access to the interior of the protected area due to new roads and trails, and increased in-migration and pressure on land for farming.

Fragmentation of habitat. Further degradation, fragmentation and destruction of the remaining small areas of natural habitat, which may eventually lead to the total disappearance of these habitats.

Extinction of plant and wildlife. Decline in the diversity and population of plants and animals of importance to conservation and local use. For instance, many globally threatened species are found in lowland forest, and some occur only in this habitat; those species would become extinct in the protected area if the remaining lowland forest disappeared.

Deterioration of watershed functions. Destruction of the vegetation cover, leads to further deterioration of watershed functions and increased occurrence of floods, landslides, soil erosion, sedimentation of rivers, poor quality of potable water, incidence of fires, and a dryer and hotter micro-climate.

Decline in fish stocks. Sedimentation of rivers and coastal waters leads to a decline in the stocks and diversity of riverine and marine fish, and degradation of coral reefs and sea grass beds, which are spawning and nursery areas for fish and crustaceans.

Marginalisation of local communities. Local communities, directly dependent on a diversity of forest and wetland resources, become increasingly marginalised and forced to engage in intensive extractive activities.

Damage of crops. Destruction of natural habitats may dislocate animals and drive them to infest or feed on crops.

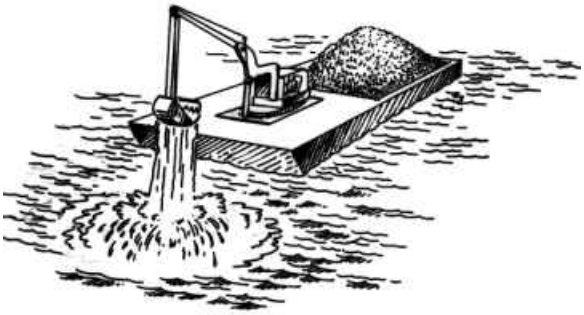
Water pollution. Mining and agricultural intensification, such as development of 'high value crop plantation' with high inputs of fertilizers and pesticides, may contaminate water sources.

Human activities that involve serious destruction of freshwater and marine habitats include:

- aquaculture development
- land reclamation for rice farming
- construction projects using rubble from corals
- charcoal and firewood production in mangroves
- fishing with dynamite, poison, compressor or electricity
- large-scale commercial fishing
- large-scale recreational tourism (with watersports, golf courses, etc.), and
- the introduction of exotic fish.

Freshwater and marine habitats may also be indirectly destroyed by human activities in neighboring or upstream areas causing pollution or sedimentation. These activities include:

- mining
- logging using bulldozers and trucks
- large-scale agricultural development (including piggeries)
- industrial development (including pulp and sugar mills)
- urban development
- road construction, and
- excavation of sea and riverbed materials.



In freshwater and marine areas, you should be on the lookout for situations of over-harvesting of fish and other species, as this will happen easily here where effective extraction methods can be used.

A summary of the impact of destructive human activities in or adjacent to freshwater and marine protected areas are provided in Box 15-2.

Box 15-2. A summary of the common impacts of destructive human activities in or adjacent to freshwater and marine protected areas.

Mining, logging using bulldozers and trucks, large-scale agricultural development, industrial and urban development, road construction, and excavation of river and seabed materials - in the area as well as in neighbouring or upstream areas: Siltation of wetlands. Organic and chemical pollution of wetlands.

Aquaculture development: Destruction of mangroves. Organic pollution.

Land reclamation for rice farming: Destruction of swamps and estuaries.

Construction projects using rubble from corals: Destruction of coral reefs.

Charcoal and firewood production in mangroves: Destruction of mangroves.

Fishing with dynamite, poison, compressor or electricity: Overharvesting of undersized fish. Destruction of spawning and nursery grounds.

Large-scale commercial fishing: Overfishing of commercial fish and other species. Destruction of sea bed habitats by heavy equipment.

Large-scale tourism: Collecting of corals. Destruction of coral reefs. Organic pollution.

Introduction of exotic fish: Extinction of fish species through predation and competition. Unpredictable changes in freshwater ecosystems.

Human activities that normally involve minimal destruction of natural habitats but which may affect single species in forest, freshwater and marine habitats are (Box 15-3):

- hunting,
- fishing and shell-fish gathering, and
- gathering of non-timber forest and wetland products.

Small-scale tourism, such as camping and hiking, is a special case that can sometimes cause severe disturbance (when it is targeted towards rare species or sensitive ecosystems such as coral reefs) but which usually has only a very limited impact (although it may occasionally lead to the desecration of the sacred places of indigenous communities).

Box 15-3. A summary of the common impacts of hunting, fisheries and gathering of non-timber forest and wetland products when undertaken beyond sustainable levels.

Decline in availability of resources. A decline in the availability of plant, animal and fish resources that are important for local food and income.

Decline in populations of threatened species. A decline in the local populations of species of plants and animals that are important to conservation.

Increased competition for resources. With the decline in resources, people need to travel further into the park to find resources and harvesting methods become increasingly destructive. Competition over the utilisation of resources intensifies. Most affected are the indigenous people and poorer households, who are further marginalised.

2 Identifying whether any management intervention is appropriate. We hope that you now know whether the change you have observed is likely to have been caused by human activity and, if so, which human activity is the cause.

In order to identify whether any management response is appropriate, examine the typical causes of destructive human activities (Box 15-4) and the possible management responses below.

Important management responses by the PASu or CENRO in charge could be to:

- **Disseminate information to authorities.** Disseminate information to relevant authorities on the conservation needs and problems faced by the protected area due to encroaching development projects, and to discuss and agree upon solutions. PAMB may find it necessary to make recommendations for the DENR Secretary to take action. Relevant authorities include the DENR Regional Executive Director's Office, Local Government Units, Department of Agriculture, Development Councils, Governor's Office, etc.

- **Strengthen co-ordination among government agencies.** Strengthen co-ordination among government agencies involved in resource use and conservation in and adjacent to the protected area. This can be done by (1) participating in meetings on land-use development, (2) ensuring that decisions at municipal and provincial level do not lead to destruction of the forest, freshwater and marine habitats in the protected area; and (3) continuously bringing up forest, freshwater and marine issues at meetings with the Sangguniang Bayan.

- **Delineate protected area zones and boundaries.** Delineate protected area management zones and boundaries by mapping, ground truthing and monumenting. Establish areas in the vicinity of communities, which will be for the sole use of people from these communities. These areas should accommodate their needs for fishing, hunting and forest product gathering and, within a smaller part of this area, farming and household supply of timber. Establish agreements on land use and quotas and state criteria for adherence to the agreed land and resource use in a contract.

- **Delineate fishing grounds**. Delineate fishing grounds with local communities and the local government in order to make it clear where the different barangays/sitios have their fishing rights and responsibilities for implementing fishing regulations.

- **Enforce fishing regulations**. Continue to persuade municipal and other government authorities to enforce fishing regulations. Use PA staff in collaboration with the local government and deputized PA rangers from the local communities to enforce fishing regulations.

- **Support processing of "tenured migrant instruments" and "ancestral domains".** Support a fast and efficient processing of "tenured migrant instruments" and "ancestral domains" in order to provide an incentive for the sustainable use of the land, to minimise land speculation, and to encourage PA communities to prevent people from expanding destructive activities in forest, freshwater and marine areas.

- **Raise awareness among local people**. Raise awareness among local communities of specific conservation needs, the role of local people in protected area management, and observed destructive practices in resource use.

- **Strengthen staff capacity.** Further train, support and deputize local forest guards. Strengthen the capacity of enforcement rangers in community approaches such as their style of communication and in establishing dialogue with community members. PAMB may find it necessary to recommend to DENR that they obtain more operational funds.

- **Support the implementation of livelihood projects**. Support the implementation of livelihood projects that seek to use the resources in a sustainable manner or that enhance an interest in resource conservation. Ensure that mechanisms to mitigate overuse of resources are in place.

- **Establish sanctuaries and closed seasons**. Discuss and agree with PA communities and local government on:

  - the establishment of fish/freshwater/marine sanctuaries and/or closed seasons for fishing,

  - the establishment of a system of closed season, quotas or zones for hunting and gathering of other selected species, and

  - the prohibition of capture, trade and possession of products from the most endangered species.

- **Issue municipal ordinances**. Encourage barangays and municipalities to issue ordinances supporting PA regulations and PAMB resolutions.

The Focus Group Discussions will probably have given you valuable information on possible solutions as perceived by the communities. Discuss your ideas with the Community Monitoring Groups, the PASu or CENRO in charge and other knowledgeable persons, and make sure you avoid any hasty conclusions.

Box 15-4 Typical causes of destructive human activities.

Destructive human activities in and adjacent to parks are often caused by:

1) **Inadequate co-ordination between government agencies**. The NIPAS Act is sometimes implemented in isolation from other development programs in and around the park, because of inadequate co-ordination between different government agencies and an unclear division of authority. Sometimes, the PASu or CENRO in charge and PAMB are not, in practice, in control of the provision of land use permits, rights or titles to land in the park; these may be controlled by Local Government Units and other government agencies that do not prioritise the NIPAS Act.

2) **Unclear demarcation of management zones**. Insufficient demarcation, on the ground, of Alienable and Disposable zones, park boundaries and zoning to guide people as to what activities to undertake where.

3) **Lack of security of tenure over land**. In forest areas, lack of security of tenure over land on the part of park communities encourages land speculation and creates opportunities for people to claim new land by swiddens. It is a disincentive to investing in sustainable land use (i.e. conservation measures, soil fertility improvement), and it leaves park communities powerless in trying to prevent people from expanding destructive human activities in the forest areas. Likewise, in freshwater and marine areas, lack of responsibilities and rights over specific fishing grounds on the part of local communities at barangay level encourages overfishing.

4) **Limited environmental information available**. Destructive practices may not be recognised if there is a lack of knowledge among park communities and park staff on local environmental issues, for instance, the status of threatened species, or the relationship between forest degradation and the productivity of coastal and other ecosystems. In addition, decision makers sometimes do not recognize freshwater and marine habitats as being of crucial local and ecological importance, and their destruction is thus not regarded as a serious problem.

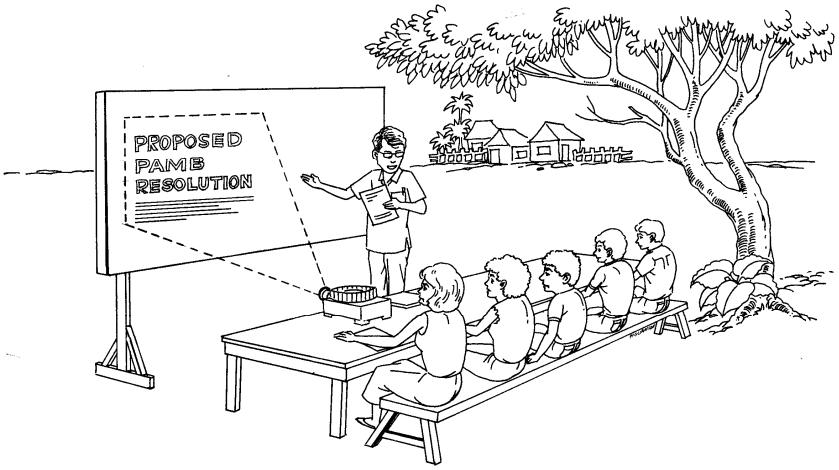
5) **Insufficient and inappropriate monitoring and enforcement**. Park rangers may lack appropriate training and operation funds to implement the laws. In addition, there may be a poor relationship between enforcement rangers and park communities and no participation on the part of local people in monitoring and enforcement. Rangers may be seen by locals as concentrating their enforcement efforts on local people's use of timber and non-timber forest products for household consumption rather than apprehending those involved in the commercial cutting of timber, dynamite/electro-fishing, and other more destructive human activities.

6) **Minimal follow-up to legal actions against major offenders**. In some areas, serious violations of the NIPAS Act by powerful groups may not be followed with legal actions. Sometimes, local government agencies may be involved in, or protecting, seriously destructive human activities in the park; this makes enforcement even more difficult.

7) **Other reasons**. In wetlands, another important reason is that methods for the sustainable use of the freshwater and marine resources are often not extended and supported. In forest areas, other important causes, particularly for kaingin cultivation, are poverty, a decline in the land area available for swiddening, and few cash-generating livelihood options for the park communities. Traditionally, kaingin cultivation was a fairly sustainable practice but today kaingin has become unsustainable in many areas due to a decline in the land area available for farm plot rotation and a decrease in the use of traditional soil conservation measures. Kaingin is rooted in poverty, a lack of land and alternative farming practices and limited income generating possibilities.

16. Presentation of biodiversity monitoring to the PAMB

It is important to inform the Protected Area Management Board (PAMB) about your biodiversity monitoring so that they can decide on appropriate mitigating measures in response to your findings.



Who should present the BMS results to PAMB? The presenter should be the PASu or CENRO in charge, alternatively the Assistant PASu. The BMS Coordinator should assist.

When do you schedule the presentation? When you prepare your annual Work and Finance Plan, you should include your presentation to the PAMB Executive Committee (Execom) quarterly on a continued basis. The first presentation should be scheduled for the first PAMB Execom meeting. If you have already been monitoring biodiversity for some time, you should include the BMS results and recommendations in your presentation.

Before you make the presentation. Ensure that you have enough time to prepare your choice of maps and audio-visuals for the presentation. Begin the preparations at least a week before the meeting. It is strongly recommended that you do a test run of the presentation to make any needed adjustments.

Read and study the Department Administrative Order (DAO) on the BMS and the DAOs on Users' Fees and Tenurial Instruments. Read the BMS Manual and the BMS Fact Sheet so you are prepared for questions.

When you make the presentation. Make the presentation in a way that ensures the active participation of the PAMB members. Get them to raise questions. Facilitate a discussion amongst them regarding what actions should be taken.

Use a mix of bullet form verbal presentation of facts and distributed fact sheets in local dialect. Support this with maps (scale 1:100,000 or 1: 50,000 or in overhead form) and plates of priority species and resource uses. You may also wish to use whiteboard or manila-paper. Make sure that everyone can see, read and hear what you are presenting.

If your presentation lasts more than 30 - 40 minutes, include an "ice-breaker" or a short break of five minutes. Otherwise the PAMB members will lose concentration and they will forget much of what you present.

Do the presentation slowly. Repeat the most important facts to ensure they understand the points you are making. End your presentation by summarizing the most important messages. Leave time for an open forum where questions can be raised and answers given by you or the PAMB Chairman.

The first PAMB presentation.

STEPS

1 Begin the presentation by summarizing the responsibility of the PAMB and the local government to oversee that the biodiversity of the protected area is maintained. The biodiversity includes species important for continued resource use by the indigenous people and the protected area tenured communities, as well as habitats/ecosystems, and wildlife populations and species that need protection.

2 Highlight the fact that the focus of the BMS is to identify trends in biodiversity and its use so as to guide the PAMB in their decisions. In addition, the BMS aims to improve the participation of indigenous people and other protected area communities in resource management and protection, in close collaboration with the protected area staff.

3 Introduce the BMS DAO, specifically, the role of the PASu and the PAMB (as expressed in its Section 4.3, paragraph 2):

- "The information provided by the PASu [regarding the results of the BMS] shall be used as a basis by the PAMB in coming up with management decisions for its concerned protected area".

4 Mention that the BMS can also provide information that might be useful for monitoring the access to and sustainable use of resources as prescribed in the DAOs:

- Guidelines and Principles in Determining Fees for Access to and Sustainable Use of Resources in Protected Areas (No. 2000-51)

- CBRM-programs under Establishment and Management of Community-based Projects and Tenurial Instruments within Protected Areas (No. 2000-44).

5 Make a short and precise bullet-form lecture on:

- What is the DENR Biodiversity Monitoring System or BMS? (Section 2)

- Why monitor biodiversity? (Section 1)

- For how long is biodiversity to be monitored? (BMS Fact Sheet)

- What can the PA management expect from the system? (Box 2-1)

- Why is the BMS particularly designed for the PA staff and the communities? (BMS Fact Sheet)

If necessary, explain to the PAMB that if the PAMB does not permanently monitor what is happening to the biodiversity and its use and to the areas critically important to conservation, it will be unable to fulfil is mandatory role and functions under the NIPAS Act.

6 Present your biodiversity baseline information per municipality. This means presenting a map showing:

- The most important areas for conservation of species and ecosystems;
- The main community resource use areas (tenured migrants and indigenous people, and areas under DENR/PAMB resource use permits);
- Location of the most serious threats;
- Location of established or planned biodiversity monitoring sites divided into the different BMS methodologies (Community Monitoring Groups, patrol routes where Field Diary is regularly used, Photo Documentation sites and Transect routes).

7 Distribute as hand-outs:

- List of those resources that are being used by the communities or other stakeholders (e.g., under DENR/PAMB resource use permit) and monitored by the BMS. Indicate the use and conservation status of each resource.
- List of the habitats being monitored.
- Plates or photos of the main monitoring species, if possible.

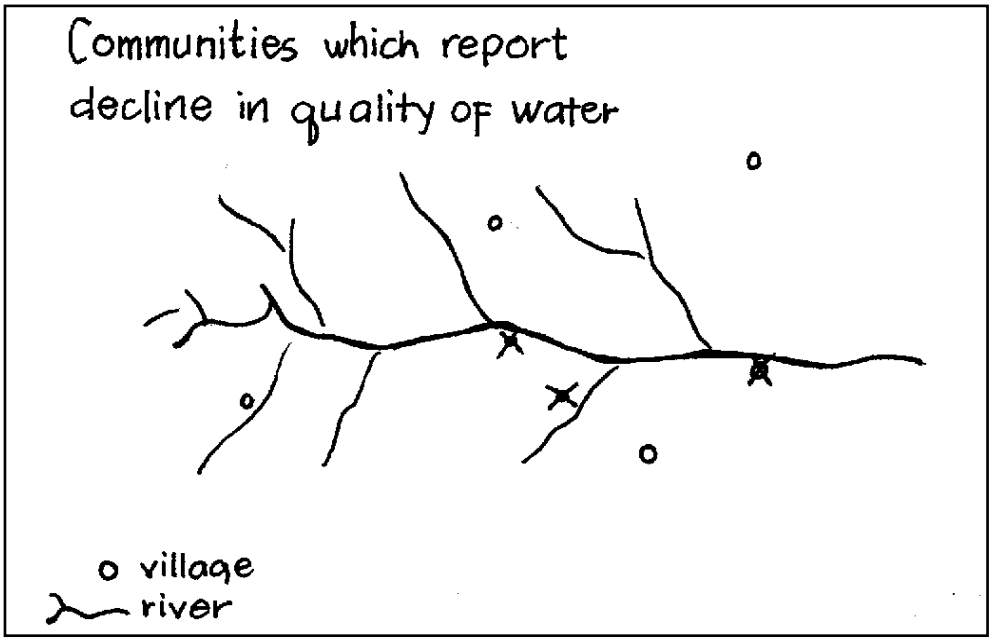
8 Present the BMS organizational structure (Section 3). Describe the flow of data from collection and analysis to presentation to the PAMB and decision-making (Figure 5-1). Explain the link between PAMB and local government, Sangguniang Bayan, DENR Regional Office, PAWB, PASu, the BMS Coordinator and monitoring persons and groups involved (PASu/CENRO Rangers, Community Monitoring Groups, volunteer forest brigades and indigenous people, NGOs and CBRM-communities).

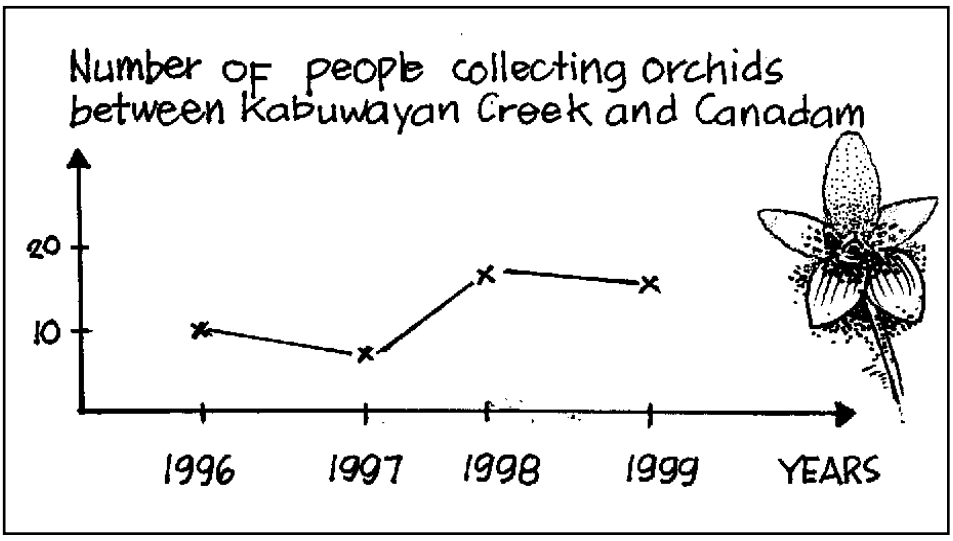
Forthcoming PAMB presentations. In subsequent presentations you will describe the status of work on the BMS in the PA and present the analyzed results and proposed actions. If there is a need to refresh the PAMB on the fundamentals of the BMS, you can begin with a brief summary of the first PAMB presentation.

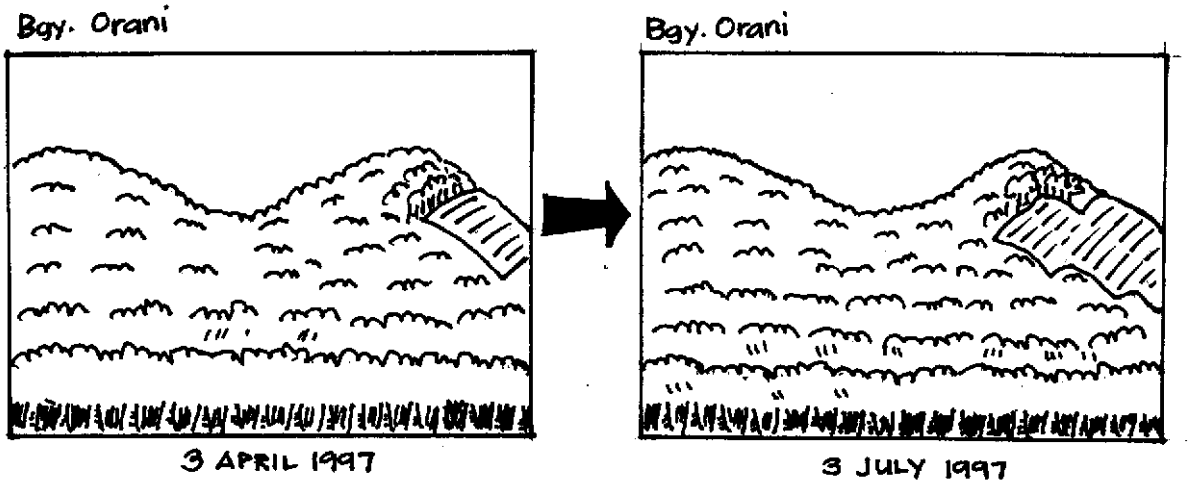
Annex 1. Display of data

Graphs and charts serve as useful devices for summarising, simplifying and presenting data in a readily understood format. All graphics should be easy to understand without any explanatory text. Graphics should not present an overwhelming amount of information but should remain simple.

Below are a few examples of the many ways in which you can graph data from the Biodiversity Monitoring System.



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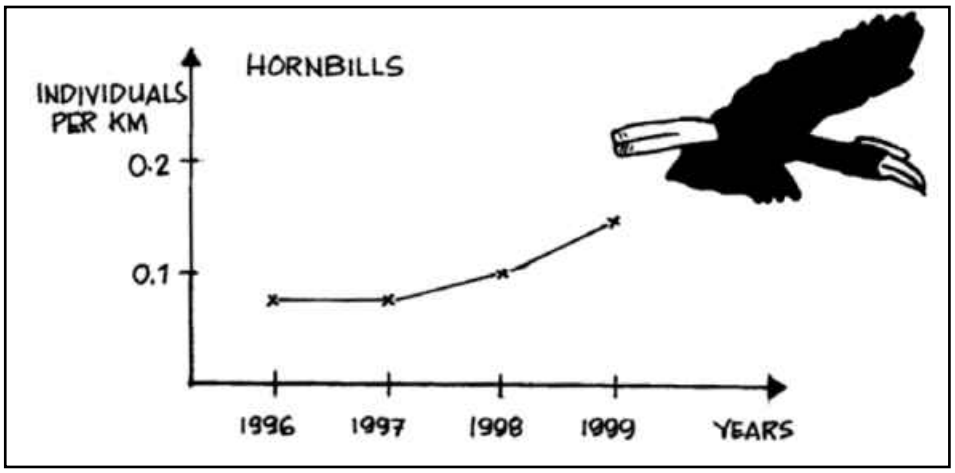
HORNBILLS
INDIVIDUALS PER KM
0·2
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1996
1997
1998
1999
YEARS

Annex 2. How you can introduce the Biodiversity Monitoring System to the protected area communities

TAGALOG VERSION

Paraan ng pag-pakilala ng Biodiversity Monitoring system sa mga nakatira sa parke.

1. Pagpakilala ng sarili (Sabihin ang iyong pangalan, trabaho, pinanggalingang lugar)

2. Ipaliwanag kung paano nabuo ang parke at mga susunod na mangyayari. Ang ating pamahalaan ay nagpasiya noong ...[petsa] na ang mga likas yaman sa lugar na tinitirahan ninyo at ang mga karatig na pook ng ...[sabihin ang pangalan ng bundok o lugar] ay dapat gamitin sa likas-kayang paraan at pangalagaan. Ang pook na ito ay tinawag na ...[sabihin ang pangalan ng parke]. Ako at ang mga kasamahan ko rito sa parke ay inatasang makipagtulungan sa inyo sa pangangalaga ng pook na ito. Patakaran ng pamahalaan na ang pagtutulungan nating lahat ay ang pinakamabisang paraan upang tuluyang mapangalaan ang parkeng ito sampu ng mga gubat nito at mga hayop na nakatira rito.

3. Pagpapaliwanag ng mga layunin ng pagtatag ng parke. Sa dahilan na isa ito sa kakaunting lugar na natitira sa bansa na may magandang gubat/katihan na mahalaga sa pagbibigay ng malinis at matatag na daloy ng tubig, at tirahan ng hayop at halaman na naubos at hindi na maaring matagpuan sa ibang lugar sa bansa at sa buong mundo ... magbigay ng halimbawa ... maraming benepisyo/pakinabang ang binibigay ng parke katulad ng isda, hayop at mga produktong gubat sa mga tao sa parke. Nais siguraduhin ng ating pamahalaan na hindi mawala ang natatanging lugar nang sa gayon ay patuloy na makinabang kayo at lahat ng tao sa ating bansa.

4. Ipaliwanag kung paano makikipagtulungan ang tauhan ng parke sa mamamayan. Tutulungan kayo upang malaman ang pamamaraan ng:

- Tamang pamamaraan ng paggamit ng mga hayop at halaman kung saan mga ito ay hindi maaaring maubos o mawala,
- Pangangalaga ng kagubatan sa pagkasira nito,
- Mapabuti ang pangangalaga sa mga hayop at halaman na kakaunti na ang populasyon katulad ng (magbigay ng halimbawa),
- Mabuting paraan ng pagtatanim, paggamit sa gubat/katihan, pangangaso at pangingisda na hindi makakasira sa kagubatan at katihan,
- Mapangalagaan ang inyong karapatan sa paggamit ng lupa, tubig, produktong galing sa gubat at mga hayop sa inyong lugar na napapaloob sa tamang limitasyon at naaangkop sa inaprobahan ng PAMB at LGU.

Mangyayari lang ito sa pamamagitan ng patuloy na pagbisita sa inyong lugar upang makipagtalakayan, makapagbigay ng mungkahi, na sana matulungan kayo sa susunod na taon at mga panahon pang darating.

5. Nagpunta po kami dito sa inyong lugar upang malaman kung nais ninyong makipagtulungan sa amin na alamin ang anomang mga pagbabago sa mga hayop at halamang ligaw o "wild plants and animals" na nakikita dito sa inyong lugar patinarin ang paggamit sa inyong kagubatan/"wetland" upang mas mapangalagaang mabuti at mapakinabangan ito sa tamang paraan.

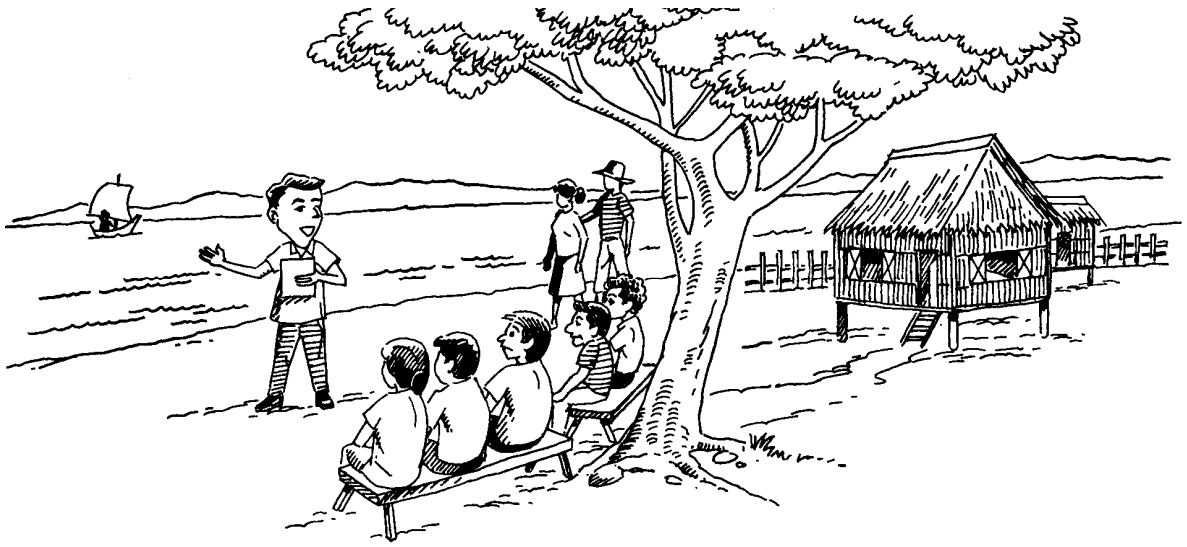
Kung kayo po ay interesado sa aming mungkahi, maaari po bang maanyayahan ang sampo hanggang labing-limang (10-15) katao na sumasangayong makipagtulungan sa amin na kumuha ng mga datus o mga impormasyon ukol sa mga hayop at halaman ang ligaw pati na rin ang mga gamit nito sa komunidad.

At kada tatlong buwan, babalik kami upang makipagpulong/ talakayan sa inyo ng isa hanggang dalawang oras tungkol sa inyong obserbasyon sa mga likas-yaman sa inyong lugar. Mabuting makasama sa gawaing ito ang mga taong meron ng karanasan sa pagtatrabaho sa komunidad tungo sa pangangalaga ng likas yaman (tulad ng "forest guards, community forestry committee members", etc.) o kaya ay ang mga taong karaniwang gumagamit at nakikinabang sa ating kalikasan.

Nais din nating makasama ang mga dalubhasa sa panggagamot o albolaryo, mangangaso at mga nangunguha ng kapakipakinabang na producto sa kagubatan/wetland. Kada taon ay nais naming magkakaroon tayo ng talakayan kasama ang buong sitio/barangay upang ipaalam sa kanila ang tungkol sa naging resulta ng ating pagsusuri/obserbasyon at makapagbigay din sila ng kanilang sariling obserbasyon at pananaw.

6. Ipaliwanag kung paano magtatrabaho ang mga empleyado ng parke sa iba pang pamamaraan.

Magtatrabaho kami rito at sa ibang lugar upang matalakay ang mga "issues" tulad ng : pagpigil sa "commercial hunting" at "gathering" na ginagawa ng mga dayuhan, ang pagiwas sa "development" na makakasira sa parke, ang pakikipagugnayan sa ibang agencia, ang pagpigil sa malawakang pagtotroso, at ang pagbibigay ng mga impormasyon sa komunidad na napapa- loob sa parke at iba pa.



ENGLISH VERSION

1. Introduce yourself (NAME, JOB, WHERE YOU COME FROM).

2. Explain how the protected area has been established and what will happen in the future
The Philippine government decided in ... that the area you are living in and the area within ...NAME OF GEOGRAPHICAL FEATURES... shall be an area in which the use of the natural resources shall not destroy the resources in the long term, and where conservation is very important. This area is called ...NAME... I together with other protected area staff in the area have been given the responsibility for working with you for the best conservation and use of the area. It is the policy of the government that collaboration between you and us, both expressed by protected area staff working directly with you and by the working of the Protected Area Management Board as representing your interests, is the best way to make sure that the protected area remains with good forest cover/water quality/wetland resources and with many different animals and plants when your children and their children grow up.

3. Describe the reason for establishment of the protected area
The protected area was established because it is one of the few remaining areas in the country with good forest/wetlands which are important for providing a clean and stable supply of water, and because it is home to animals and plants that have been wiped out in most other places in the country and in the world ..NAME A FEW.. The area is also providing many benefits such as fish, animals and forest products to many people in the area. The government wants to ensure that this unique area is not disappearing and is for the benefit of both you and people in the country as a whole.

4. Explain how the protected area staff will work with villagers
We will be able to work with you in order to assist you in seeking ways:

- of using the wild plants and animals in your area in such a manner that they are not disappearing,
- of better protecting the forest and wetlands from destruction,
- of improving protection of those wild animals and plants that are getting very rare such as NAME A FEW,
- of improving the methods for farming, use of forest/wetlands, hunting and fishing in such a way that they are not destroying the forest and wetlands,
- of securing your rights to use the land, water, forest products and wild animals in your area within certain limits and in a way that is approved by the Protected Area Management Board and Local Government Units.

We are able to do this by visiting your village frequently to discuss, maybe advise and hopefully assist you during the coming year and maybe longer.

5. Explain the objectives and activities of the Biodiversity Monitoring System
I have come to your village today because we would like to know if you will work with us to observe changes in the numbers of wild plants and animals and in the use of the forests and/or wetlands for the best conservation and use of the area. If you are interested, we would like to find 10-15 local people who are willing to collect data on wild plants, animals and resource use, and who will spend two hours with me every quarter so that I can listen to, and we can discuss, their observations. It is best if those people are involved with community work within natural resource management (forest guards, community forestry committee members, etc.) or villagers otherwise interested in the use of forest/wetland resources. We

would like the most experienced indigenous healer and all-round hunter/forest product gatherer and fisherpeople to be members of this group. EXPLAIN POSSIBLE ISSUES YOU WOULD LIKE THEM TO LOOK FOR BUT SAY THAT THEY MIGHT HAVE BETTER SUGGESTIONS. Every year or so we would also like to discuss the findings with the whole sitio/barangay so that we can tell them about your findings and get input and responses from all members of the sitio/barangay.

6. Describe how the protected area staff will work in other ways
We will also work in other villages, and we will work, both here and other places, on issues such as: trying to stop commercial hunting and gathering by outsiders, trying to prevent developments that will destroy the protected area, co-ordinating with other agencies, preventing large-scale logging, providing information to protected area communities and others, etc.

Annex 3. Indicative budget for monitoring biodiversity

Below is a budget for establishing and running the Biodiversity Monitoring System (BMS) as part of the main operations in a protected area.

This example is based on a protected area with a size of 30,000 hectares (such as Mt. Kitanglad Range Natural Park). Assumptions are that a minimum of 6 protected area rangers participate (assisted by volunteers such as deputized forest brigade members, indigenous people, etc.), and that 10 Community Monitoring Groups, 5-10 Photo Documentation sites, and 3-5 Transect Walks/Cruises/Swims are established.

All prices in Philippine Pesos (1 USD = 45 PhP, August 2000).

EQUIPMENT COSTS

1) Equipment Outlay above PhP 10,000 (DENR budget expense class 300-36)	
Binoculars 6 x 10,000/item	60,000
Camera 2 x 12,000/item	24,000
GPS 1 x 15,000/item	15,000
2) Equipment Outlay below PhP 10,000 (DENR budget expense class 200-07):	
Compass 6 x 1,000/ item	6,000
Tripod 2 x 3,000/item	6,000
Ranger Field Gear 6 x 7,000/item	42,000
Additional equipment in marine protected areas:	
Marine Bottom Glass Box 2 x 3,000/item	6,000
Snorkeling Field Gear 4 x 5,000/item	20,000
Total	179,000

RECURRENT COSTS

1) Travel (DENR budget expense class 200-02):	
Travelling expenses and honoraria	
6 PA rangers/BMS assistants, 10 days per quarter x 4 qtr. x PhP 300	72,000
2) Field Supplies and Materials (DENR budget expense class 200-07)	
(incl. films/film processing, batteries, markers, paper sheets, xeroxing, snacks)	30,000
3) Other Services (DENR budget expense class 200-29)	
Focus Group Discussion - Community meetings,	
10 community meetings x 4 quarters x 1000/meeting	40,000
Total	142,000

The expenses can be classified as part of the protected area's core operational budget (the yearly Recurrent Costs or Maintenance and Other Operating Expenses).

Since the BMS methods should be undertaken by the PA or the deputized forest rangers during their regular patrolling (except the Focus Group Discussion with Community Monitoring Groups), the budget for travel and per diem should only reflect the additional costs of carrying out BMS work in areas away from the regular patrol routes.

Source: PAWB-DENR Work-shop on Monitoring Biodiversity, May 1998; DENR *in litt.* 2000.

Annex 4. Filled in data sheets from Focus Group Discussions

This annex comprises examples of filled in Focus Group Discussion (FGD) data sheets from a land (freshwater wetland or forest) and a marine area. It comprises three formats: Format 1, Format 2 and Format 3.

EXAMPLE FROM A LAND AREA

Bgy. Morong, Mt. Kanlaon Natural Park
April – June, 2000

FORMAT 1

MAIN ISSUES DISCUSSED

Resource uses chosen for monitoring:

- Hunting of wild pigs,
- hunting of wild deer,
- freshwater fish catch,
- use of household timber,
- lobster catch.

Hunting of wild pigs.
The Group stated that hunting of wild pigs has decreased since last quarter but this was attributed to seasonal changes and not to a decrease in the pig population. There was no change in the number of people involved in hunting wild pigs since last quarter, only normal seasonal changes. However, the number of wild pigs is still below what it was in previous years. The barangay has therefore recently decided to establish a closed season for hunting in December and January. Blasting of wild pigs is practised, particularly in the fields, in order to prevent pigs eating the rice. There was a short discussion on blasting around how to solve the fact that blasting is illegal according to the law but considered important for the protection of the rice harvest. No solution was found but the discussion will continue.

There are still very many traps. The Group discussed the need to limit the number of traps; no agreement was reached within the Group but all agreed that over-hunting was taking place. One of the Group members gave the example that it took 4 days to catch one pig with 3 traps in the vicinity of lower Blos River.

All pigs are reported to have been consumed within the Barangay, with some of the pigs being sold to other barangay members (should be continued with results on the other resource uses, hunting of wild deer, catch of freshwater fish, use of household timber, catch of lobster).

Format 2
MATRIX FOR RESOURCE USES

Resource use	Place extracted	Method of Extraction	Quantity extracted by CMG members	Quantity extracted by others in the Bgy.	Total number of days/hours spent in extraction by CMG members	Use and other remarks
Wild pig	Upper and lower Blos and Dicaduan	Blasting: 5 SiloL: 13 Bow: 1 Gun: 2	8 heads by 3 members	13 heads by 5 people	14 days spent by 3 members to catch 8 heads	Seasonal changes, see the discussion
Deer	Upper Blos	Silo: 5 Bow: 2	3 heads by 2 members	4 heads by 2 people	4 days spent by 2 members to catch 2	Domestic use
Fresh-water fish	Blos River, Diaduan River	Spear: 45 kg Gill net: 150 kg Electro: ? Unknown: 8 kg	48 kg by 5 members	155 kg by 13 people	Total of 35 hours spent by 5 members to catch 48 kg	Domestic use. See the dis-cussion
Household timber	Near Centro			1 log of Red Lawan		For irrigation system
Lobster	Bolos point	Light on reef (15 kg)	12 heads by 1 member (c. 15 kg)	No reports	5 nights of approx. 5 hours	Commer-cial use
Monkey	In the fields and in Blos	Silo: 4 Gun: 8	7 heads by 4 member	5 by 3 people	No records	Food, but also seen as a pest
Water Monitor Lizard	Lower Blos and Diduan	Silo: 17 Other: 4	8 by 5 members	13 by 7 people	5 members spent 10 hours to check traps	Domestic use
Junglefowl	Whole forest	Silo: 26	10 by 3 members	16 by 6 people	3 members spent 20 h	Domestic use
Hornbill	Whole forest	Gun: 4	4 by 2 members	No reports	No data	Domestic use
Turtle/ Turtle eggs			None	None		
Rattan			None	None		
Timber poaching			None	None		
Kaingin			None	None		

Format 3
MATRIX FOR SPECIES OBSERVED

Species	Place	Numbers	How observed	Date	Name of observer	Remarks
Turtle	Bolos Point Diaduan Beach	1 1	Seen swimming in sea. Nest found	Mid April 10-4-00	Teddy Anuan Larry Subia	 Eggs were not collected
Crocodile	Croc. Sanctuary	1	Track	4-4-00	Gener Cabaldo	Very large maybe 6 m
Phil. Eagle		None				
Parrot	Upper Blos	10	Seen	April	3 different people	Seen in small groups
Taractic Hornbill	Whole forest	20-25	Seen / heard	All of the quarter	Many people	Still very common
Rufous Hornbill	Upper Blos	10-14	Seen/ heard	All of the quarter	Many people	Still common
Wild duck	Lower Blos	40-50	Seen	All of the quarter but most in March	Many people	
Tabon bird		None				
Python	Lower Blos	1	Seen	March	Jerry Ramirez	Around 4 m

EXAMPLE FROM A MARINE AREA

Bgy. Didadungan, Northern Sierra Madre
January – March, 2001

FORMAT 1
MAIN ISSUES DISCUSSED

Resource uses chosen for monitoring:
- marine fishing,
- collection of shellfish,
- catch of lobster.

Marine fishing.
The Community Monitoring Group stated that marine fishing had declined during the last quarter. This was thought to be due to bad weather conditions, which made fishing difficult. Compared to the same time last year, the fishing is believed to be more or the less the same, with no perceived change in catch per unit effort for this season.

No change in number of barangay people involved in fishing. However there is a reported increase in outsiders fishing within the waters of the barangay. The outsiders use very small mesh-sized nets close to the coral reefs. The barangay chairman has reported to the municipality on the encroachment of outsiders, but nothing has happened. The Group agreed to follow up with the barangay council and with the PAMB through the PASu. If increase in fishing efforts by outsiders continue, the Group fear that their own catch would decrease due to over-fishing. The possibility of closing some of the coral reefs for fishing was discussed but not agreed upon. They will continue to try to prevent outsiders from fishing.

Use of dynamite fishing is minimal, with only one reported case during the quarter. The same amount of marine fish is still sold to commercial buyers, although there is increasing demand for fish on the part of the buyers (should be continued with results on the other resource uses, collection of shellfish and catch of lobster).

FORMAT 2
MATRIX FOR RESOURCE USES

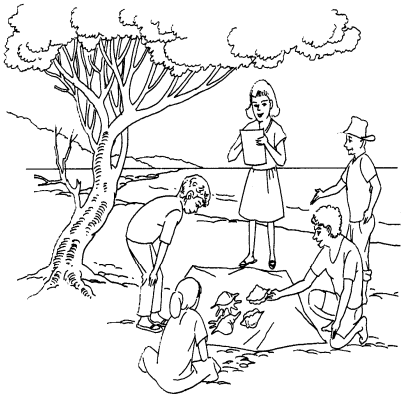
Resource use	Place extracted	Method of Extraction	Quantity extracted by CMG members	Quantity extracted by others in the Bgy.	Total number of days/hours spent in extraction by CMG members	Use and other remarks
Marine fish						
Yellowfin		Hook on line	Total 340 kg by 4 members	> 1000 kg 12 boats	Total of 20 days by 4 members	50% sold
Lapulapu		Hook on line	Total 690 kg by 3 members	> 2000 kg 12 boats	Total 15 days by 3 members	100% sold
Coral fish		Gill nets /spear	Total 800-900 kg by 6 members	Unknown	Total of approx 25 days by 6 members	Domestic use
Lobster	Reef area outside sitio Lanang	Trap and light	12 pieces by one member	15-20 by 3 people	Total 8 nights by one member	100% sold to dealer from Didian
Other shellfish	Reef flats Bicobian	Collection by hand	Total 48 kg by 2 members	Unknown	Total of 50 days by 2 members	Domestic use
Catch of fish using illegal Methods	Reef outside sitio Dumag	Dynamite		7 kg		Only one instance of illegal fishing methods

FORMAT 3
MATRIX FOR SPECIES OBSERVED

Species	Place	Numbers	How observed	Date	Name of observer	Remarks
Turtle	All water Beach near sitio Dumag	8 1	Seen swimming Tracks on beach to nest	Start April and end March April 6	C. Lopez and W. Auan C. Lopez	Nest same place as last year. Eggs were already collected.
Dugong		None				
Sharks	All water	Plenty	Seen Swimming	All quarter		Still many, but maybe decreasing
Nesting seabirds	Spires Island	60-70 individuals	Seen on nest and flying	March/ April	D. Luang	Last year same time there were more than 100 nesting pairs
Whales	4-5 km off Spires Island	4 very large	Seen Swimming	Feb. 20	W. Auan	Probably Sperm whale according to description.
Dolphins	All water	Plenty seen. More than 20 times. Group size from 3 to at least 150 individuals	Seen swimming	Most in March		More seen this quarter than last quarter

Annex 5. How to monitor the fishery with Focus Group Discussions

The Focus Group Discussion method can be used to monitor the fishery in terms of over-fishing and overharvesting of shellfish. It can also be used to detect major changes in species composition of the fishery catch over time. This is important since fish and shellfish caught for consumption in many areas represent the resources of most value to the local communities. The Focus Group Discussion method was described in Chapter 8. Tips are given below on the use of this method for fishery monitoring.



Focus Group Discussion should be used to discuss:

- trends in effort to catch fish and other important resources,
- trends in abundance of fish and other resources,
- trends in number of fisherpeople/resource users,
- changes in fishing and extraction methods, and
- problems and solutions related to the fishery and other wetland resource use, such as illegal fishing by outsiders or electro/dynamite fishing.

STEPS IN MONITORING THE FISHERY

1 Establish Community Monitoring Groups in:
   - those protected area communities living near wetlands of high conservation value,
   - those protected area barangays and villages where there might be over-fishing,
   - those which are most dependent on fish/shellfish and other freshwater/marine resources from the protected area, and
   - those located next to proposed or established fish sanctuaries.

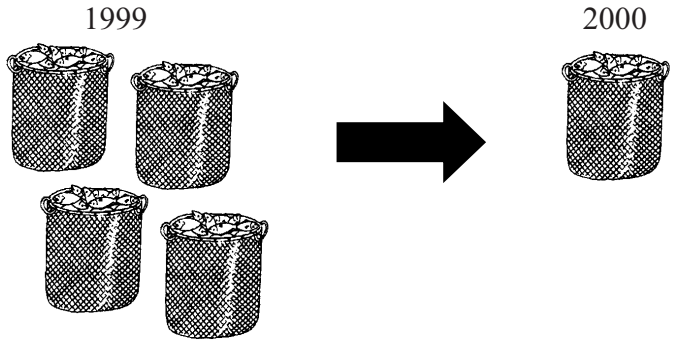
2 When you talk with barangay captains, you should explain that the aim of this monitoring is to assess the health of the fishery, that is, to ascertain whether there is any over-fishing that requires management action. Such management action could consist, for example, of reaching agreements limiting the minimum mesh size of gill nets. They could also consist of taking some pressure off the fish by encouraging fish culture in ponds on the periphery of the wetland, or introducing marine sanctuaries to improve fishing outside the sanctuaries. Some barangay captains might think that you are collecting data for taxation purposes. Emphasize that this is not the case but that you represent the PAMB.

3 Try to get the most experienced and committed fisherpeople in the protected area to participate in the volunteer Community Monitoring Groups.

4 Ask the members of the Community Monitoring Groups to keep track of their fish catches, threats to the area, use of other resources, and species observed. Follow the formats for main issues discussed, the matrices for resource uses and for species observed, given in Annex 4. For the fish catch/resource use it is important to know the weight of fish/resources caught together with the species and gear used as well as the time used to obtain that catch (Box 17-1).

Box 17-1. Why collect fishing effort data and catch data?

A trend in falling catches recorded by fisherpeople over a number of years in the absence of effort information could mean either of two things - that the fishing effort is being reduced; or that the fish are becoming scarcer; i.e. that overfishing is occurring. If the fisherpeople are recording decreased catches while the fishing effort remains constant or is even increasing, it means that there is a problem of overfishing.



Falling catches can mean reduced fishing effort or that fish are becoming scarcer.

5 Daily recording of data on the part of those who go fishing might be too large a job. If that is the case, ask them to record only during a two week period before every quarterly Focus Group Discussion you have with them. It is better to get uniformly collected data from the same individuals rather than randomly collected data from many different persons.

If any fisherpeople in the group are very keen and interested, you should encourage them to use a Fishery Record Sheet (Figure 17-1), which is an expanded version of the matrix for resource uses (Format 2, Annex 4). It is very important that not only the size of the catch but also the effort is noted (Box 17-1). The first 2-3 times they return from fishing you should go to the landing-site and help them fill in the sheet. Again, it is better to record data continuously for a fixed shorter period (two weeks or a month) than to record data on and off over the whole quarter.

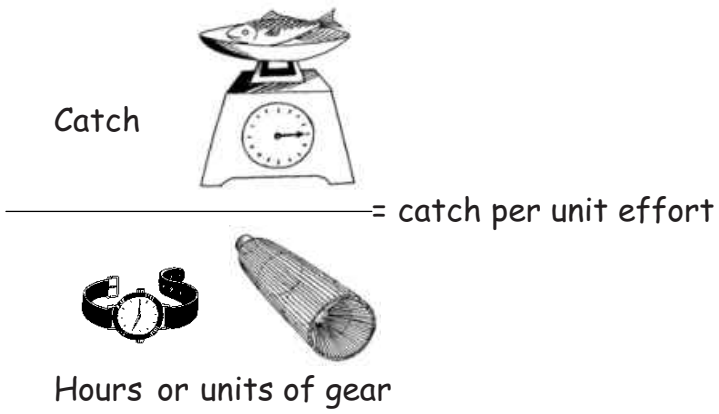
6 Please stress that the fisherpeople should also record zero values (if they go fishing but catch nothing) and any remarks they may have (e.g., on possible causes, including weather conditions and moon phase).

7 At the quarterly discussion meetings between the Community Monitoring Groups and yourself, you should look at and discuss the notes from the members and the filled-in Fishery Record Sheets. After or before the meeting, use the waiting time to calculate the catch per unit effort (CPUE, Box 17-2) based on the notes and the filled-in Fishery Record Sheets. Remember to bring an identification guide and a calculator.

8 Obtain a mean value for the catch per unit effort (CPUE) at different times of the year. In the first year, the variation in CPUE can be used to detect seasonal variations in catches. In the following years, the data can be used to detect any changes in the catch per unit effort, which can indicate the sustainability of the fishing.

9 On the same day that you are in the community, you should spend time at the fish landing site interviewing some of the fisherpeople present about the changes in the fishery. This will validate the information from the Focus Group Discussion.

Box 17-2. What is the catch per unit effort (CPUE)?



The catch data and fishing effort data are combined to give a term called the catch per unit effort (CPUE). This is the weight of fish caught divided by the effort (the time and meter of gill net) expended in obtaining it.

For example, a fisherman uses a gill net 30m long, which is left overnight for 12 hours and he catches 30 kg of fish. The CPUE for that particular night would be 30 kg of fish per 30m of gill net per 12 hours.

If another fisherman catches 100 kg of fish using a 50 m gill net and leaving it for 16 hours, then one can make these two CPUE data directly comparable by adjusting the units to weight of fish caught per meter of gill net per hour.

Result: For the first fisherman, his CPUE would be 0.83 kg of fish caught per meter of gill net per hour. For the second fisherman, his CPUE would be 0.125 kg of fish caught per meter of gill net per hour.

Tips on the analysis of fishery record data are provided in Chapter 8A.

Fishery Record Sheet

Locality: Brgy. Veruela, Agusan Marsh, Province of Agusan Del Sur

Date: 10 Dec. 2000 **Name of recorder:** Filemon Ambasakan

Fishing gear used (e.g., spear, push net, bottom gillnet, crab pot, scareline and net): Lines with hooks

Number of gear units (e.g., length of nets and longline, number of hook and number of traps): Two 50 meter lines with 50 hooks each

Length of time for gear use: four hours **number of fishing trips:** One

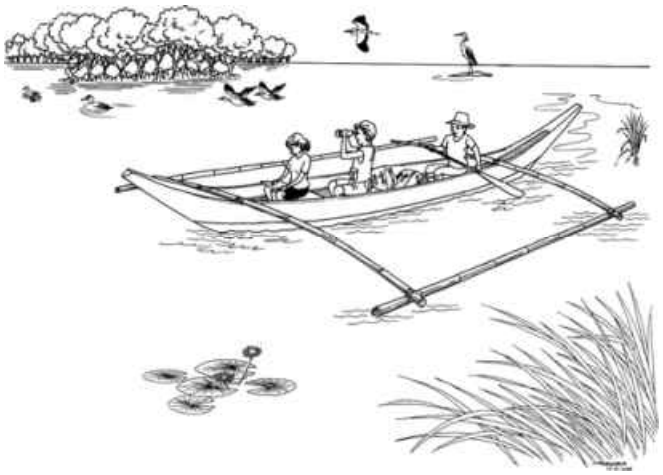
Other observations (e.g., sea state, weather and commercial fishing boats): Extensive flooding, new moon.

Kind of fish caught/shellfish gathered (local or common name)	Amount of catch (e.g., kg., volume, number)
Mudfish	2 kg
Tilapia	3 kg
Young crocodile	1 (size as a hand)
catfish (native)	1 kg
other small fish/carp	1.5 kg

Figure 17-1. Example of a filled in Fishery Record Sheet

Annex 6. Using a boat along shorelines: the Transect Cruise method

In wet areas where it is impossible to walk on foot, the Transect Walk method can be undertaken by boat. For example, along rivers, creeks, lakeshores, intertidal mudflats and mangrove channels. Except for the use of boat instead of walking, the field method and data analysis are the same as for the Transect Walk method.



PERSONNEL

Three people are needed: a boat driver, a BMS staff (observer) and an assistant (listing observations and handling equipment). It is advisable for those involved to be able to swim.

Like the Transect Walk, the Transect Cruise has to be carried out the same way every time:
1. the same amount of time to survey
2. the same distance over
3. the same rivers and shorelines at
4. the same time of day (beginning between 6 and 7 am) at
5. the same time of the year recording
6. the same resource uses and species in the
7. same way by
8. the same observer (or another with the same identification skills) and using
9. the same way to estimate numbers and
10. the same type of boat and speed (paddling).

Box 17-3. Transect Cruises: Do them the same way every time!

TIPS

When you select Transect Cruise routes, look for patrolling routes passing through:
- areas where major threats are found
- areas particularly used by the local communities (such as main rivers, lakes, mangrove forest, or coves important to fishing of lobsters)
- the major habitat types important for conservation (such as swamps, estuaries, large intertidal mudflats or small islands with undisturbed forest).

At least two Transect Cruise routes should be established in each freshwater protected area. A desirable cruise line could be a major river and smaller creeks leading to floodplains or oxbow lakes. Short trails can be walked at right angles to the waterway. The same trails must then form part of the route and be used each time.

When you establish Transect Cruise routes, sail the proposed routes and make sure that a 2 kilometre route can be established so that it passes through one or more major freshwater or marine habitat types. Start and end points should be clear land marks or marked with permanent markers. If boat views along the route are obstructed by high river banks or vegetation, you can establish short trails at right angles to the waterway (or construct simple bamboo platforms) and include them in the Transect Cruise route.

When you survey the Transect Cruise, before departure always:
- check the weather (no strong winds, no high waves, fair to overcast)
- check the water level (to judge optimal survey conditions).

You must survey the Transect Cruise route with low speed. The boat driver should paddle. On rivers you can drift with the current. Only short stops of 5-10 minutes are permitted when identifying and noting and when making observations from the short trails. A pillow is comfortable to sit on. A filled in data sheet for a Transect Cruise is shown in Figure 17-2.

FIELD DATA SHEET FOR TRANSECT

Observer: DODONG TAMSI

Location (site name): AGUSAN RIVER, FROM BINANGA TO PINAGAT

Length of transect: 2 KM

Date: 15 MARCH 2000

Starting time (TW between 6 and 7 am. TS between 9 am and 3 pm): 6:00 AM

Comments (e.g. on weather): SUNNY, NO WIND, NO WAVES, WATER LEVEL 1.2 M ABOVE THE 0 M SIGN ON THE LIGHT HOUSE

Species/use recorded	Number	Time (or distance from transect start)	Remarks on what was recorded
FISHERMAN WITH CATCH	1	6:10	9 PCS. DALAG (APPROX. 2 KG) AND 2 PCS. HITO (APPROX. 0.5 KG)
DUCKS	6	6:12	PROBABLY PHIL. DUCK (WHITE UNDERWING)
TARICTIC	2	6:25	FEEDING ON FIG TREES AT LAKESHORE
BOAT W/ LOG	1	6:40	2 PCS. OF BANGKAL LOGS (APPROX. 3 m^3)
LARGE DARK HERON	1	6:48	FLUSHED FROM FLOATING GRASS BED ON LAKE BINANGA, PROBABLY PURPLE HERON

Figure 17-2. Example of a filled in Field Data Sheet for a Transect Cruise

Annex 7.

Transect field data sheet and Photo Documentation forms

FIELD DATA SHEET FOR TRANSECT

Observer:

Location (site name):

Length of transect:

Date:

Starting time (TW between 6 and 7 am. TS between 9 am and 3 pm):

Comments (e.g. on weather):

Species/use recorded	Number	Time (or distance from transect start)	Remarks on what was recorded

DATA SHEET 1 Establishment of Photo Documentation Site

Location (site name, province, municipality, barangay, sitio):

How to get to the site:

Position (coordinates):

Position read from GPS or topographic map:

Your full name:

Date of establishment:

Number of photo angles used at this site:

Sketch map of camera location (use the rest of the page to draw a map on):

DATA SHEET 2 Establishment of Photo Documentation Site

Location (site name):

Position (coordinates):
Date:
Your full name:
Remarks:

Sketches of the photos:

	Photo name code (specific name given now to this photo): View angle: Description:
	Photo name code (specific name given now to this photo): View angle: Description:
	Photo name code (specific name given now to this photo): View angle: Description:
	Photo name code (specific name given now to this photo): View angle: Description:

DATA SHEET Photo Documentation

Location (site name):

Position (coordinates):
Date:
Photographer:
Remarks:

Viewing angle for photo:
Film number:
Photo name code (as given at site establishment):
Photo number (as indicated in the camera):
Photo number (as indicated in the negative):
Comments:

Viewing angle for photo:
Film number:
Photo name code (as given at site establishment):
Photo number (as indicated in the camera):
Photo number (as indicated in the negative):
Comments:

Viewing angle for photo:
Film number:
Photo name code (as given at site establishment):
Photo number (as indicated in the camera):
Photo number (as indicated in the negative):
Comments:

Viewing angle for photo:
Film number:
Photo name code (as given at site establishment):
Photo number (as indicated in the camera):
Photo number (as indicated in the negative):
Comments:

Viewing angle for photo:
Film number:
Photo name code (as given at site establishment):
Photo number (as indicated in the camera):
Photo number (as indicated in the negative):
Comments:

Viewing angle for photo:
Film number:
Photo name code (as given at site establishment):
Photo number (as indicated in the camera):
Photo number (as indicated in the negative):
Comments:

Glossary and abbreviations

Abbreviations

Bgy	Barangay
CBRM	Community Based Resource Management
CENRO	Community Environment and Natural Resources Office
CPUE	Catch Per Unit Effort
DAO	Department Administrative Order
DENR	Department of Environment and Natural Resources
GIS	Geographical Information System
GPS	Geographical Positioning System receiver
HNGO	Host Non-Government Organisation
LGU	Local Government Unit
NIPA	NGOs for Integrated Protected Areas, Inc.
NIPAS	National Integrated Protected Areas System
PA	Protected Area
PAMB	Protected Area Management Board
PAWB	Protected Areas and Wildlife Bureau of DENR
PAWD	Protected Areas and Wildlife Division of the regional DENR
PENRO	Provincial Environment and Natural Resources Office
SLR	Single Lens Reflex

Definition of Technical Terms

Biodiversity	the variety and variability among living organisms and the ecological complexes in which they occur
Habitat	an environment of a particular kind (such as sea shore or old forest) that provides an animal or plant with adequate food, water, shelter, and living space
Indicator for biodiversity	a parameter which points to, provides information about, or describes the state of biodiversity of an area
Kaingin	slash and burn cultivation
Monitoring	data sampling which is repeated after certain intervals of time for management purposes
Species	related plants and animals that are capable of breeding freely to produce fertile offspring
Sustainable development	development which uses natural resources in a way to meet present needs without compromising the ability of future generations
Swiddening	slash and burn cultivation
Wetland	an area that is regularly wet or flooded, and where the water table stands at or above the land surface for at least part of the year

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DENR Administrative Order
No. 2000-13

SUBJECT: Guidelines on the implementation of the Biodiversity Monitoring System (BMS) In Protected Areas.

Pursuant to Republic Act No. 7586 (NIPAS Act) and the Implementing Rules And Regulations, in line with the Philippine commitment to the Conservation on Biological Diversity, and in order to provide up-to-date and comparable information on resources as basis for the management of protected areas, the following guidelines on their implementation of the Biodiversity Monitoring System (BMS) in protected areas is hereby promulgated.

Section 1. Objectives. The BMS aims to:

1.1 Provide simple, cost-effective, and standardized methods in monitoring the trends in population of indicator/priority species and land uses in protected areas;
1.2 Systematically generate up-to-date information necessary for effective and efficient management of protected areas;
1.3 Involvement of local communities and other stakeholders in the generation of information; and
1.4 Strengthen the capabilities of the protected area staff, other concerned DENR personnel, selected members of the Protected Areas management Board (PAMB) and local communities in the data collection, analysis and interpretation.

Section 2. Scope. The BMS shall be implemented in all protected areas and shall therefore be part of the regular activities in protected area management.

Section 3. Definition of Terms. As used in Order, the following shall be constructed as:

Biodiversity - the variety and variability among living organisms and ecological complexes in which they occur

Indicator/priority species for biodiversity
- a parameter which point to, provide information about, describes the status of the biodiversity of a protected area

Section 4. Procedure in the BMS implementation. The BMS shall have the following phases:

4.1. Training. The Protected Areas and Wildlife Bureau (PAWB) shall conduct the Trainers' Training Program. The Regional Offices shall conduct subsequent trainings. Training participants shall include but not be limited to the following:

4.1.1 Protected Area Superintendent (PASu) and PA Staff;
4.1.2 Concerned CENRO representatives;
4.1.3 Concerned PENRO representatives;
4.1.4 Regional Protected Area and Wildlife Staff;
4.1.5 PAMB representatives; and
4.1.6 Local community representatives

The DENR-Human Resource Management Services shall include the training of BMS in its accredited training programs.

4.2 On-site implementation. The BMS shall be implemented by the PASu staff using prescribed methods by DENR-PAWB.

4.3 Submission of BMS Reports. The PASu, thru the CENRO, if needed, and PENRO concerned, shall submit the BMS report to the Regional Executive Director, for endorsement to the PAWB Director. The PAWB Director shall submit an annual consolidation BMS report to the Secretary. The schedule of the submission of the BMS reports shall coincide with the submission of the regular quarterly CENRO and PENRO reports.

The PASu shall also regularly submit reports to the PAMB on the results of the BMS implementation. The information provided by the PASu shall be used as basis by the PAMB in coming up with management decisions for its concerned protected area.

4.4 Monitoring and Evaluation. The Regional Offices and PAWB shall undertake the annual monitoring and evaluation of the implementation of the BMS. The monitoring and evaluation of BMS results shall be done on a quarterly basis.

Section 5. Fund Allocation. The Regional Offices shall allocate the necessary funding for the implementation of the BMS activities.

Section 6. Effectivity. This Order takes effect immediately.

ANTONIO H. CERILLES
Secretary

Expanding the Scientific Basis for

How the World Can Monitor and Manage Natural Resources

Human knowledge on the status and trends of natural resources, ecosystem services and species on earth is limited. Global environmental assessments synthesize this limited data, which is then used in decision-making. There is a serious risk that decisions are poorly targeted and not addressing critical needs.

Over the past 100 years, science has been the preserve of 'experts'. It is increasingly recognized that local community members who may not qualify as experts in conventional terms can be very knowledgeable about local resources. Moreover, local community members have an important role in the sustainable use of natural resources. The remarkable rise of technology and, in particular, mobile devices and social media, which have penetrated across the world (now also in developing regions), opens up the possibility for hundreds of millions of people to participate in scientific processes, and to gather information and obtain results that are both locally and globally relevant and potentially transformational in scope.

Across a range of ecosystems and socio-political settings, Finn Danielsen and co-workers have explored the basis for inclusive and citizen-based natural resource monitoring, and the implications for natural resource management and commitment towards conservation. In this D.Sc. thesis, the numerous case studies are analysed and put into a collected perspective. The thesis will be of interest to researchers and practitioners engaged in community-based ecosystem monitoring and management throughout the world.

"Finn Danielsen is the world leader in the field of locally-based participatory monitoring. This is a widely recognised research field of conservation science, which has been instigated and championed by Finn Danielsen, and which has contributed to both academic and policy advancement. Throughout the thesis, the ambitions and vision of Finn Danielsen to further this field are clear, combining diligent science with an applied vision for conservation."

International D.Sc. Evaluation Panel 2016