2020 EDITION

African Marine Litter Monitoring Manual

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Edited by Toshka Barnardo & Anthony Ribbink

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PREFACE

Universally, concerns are mounting over the ubiquitous increase in plastic in waterways and oceans of the world. It is commonly stated that about 80% of plastic waste enters the seas from land-based sources, of which about 90% flows down waterways to the seas. The resultant plastic pollution of the oceans is associated with serious negative environmental, ecological and economic consequences: marine life is severely affected by entanglement, ingestion and chemical pollutants; human health is also affected, and there are economic repercussions from the impacts on fisheries, shipping and tourism. Depending on local conditions, differing proportions of plastic debris end up on beaches, or sink into demersal habitats, or float off into the ocean to perhaps contribute to the oceanic gyres.

The percentages given for plastics flowing to the seas from land-based sources are generalizations based on global estimates that are not necessarily supported by solid data. They are nevertheless valuable pointers indicating firstly that management of the plastic pollution of marine environments must focus on reduction at source on land and secondly that data are required to support evidenced-based strategic planning. Yet, as noted by Jambeck and her collaborators in their global analysis of 2015 and by the authors of the Africa Waste Management Outlook of 2018, data regarding plastic waste in Africa is sparse—too sparse to use as a basis for accurately understanding the current status and inadequate for strategic planning and management. This is a concern for Africa as predictions from the United Nations and World Bank are that the population growth and development of Africa over the next three decades is likely to double the amount of waste entering the environment. Clearly, the need for data regarding unmanaged plastic litter in Africa is acute. The initiation of this litter monitoring programme by the Western Indian Ocean Science Association (WIOMSA) is an essential, welcomed first step. For data to be meaningful and comparable within and across countries, they need to be gathered in consistently standard ways. This first edition of the manual has been compiled by the teams working together in Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and Tanzania with a view to developing uniform ways of measurement. The African Marine Waste Network programme of Sustainable Seas Trust coordinated the manual.

In this first phase of the monitoring programme, the aim is to develop uniform ways of measuring litter in rivers, estuaries, along beaches and on land. This has turned out to be more thought-provoking than originally envisaged because the need to accommodate the great variability of ecosystems and yet produce comparable data is challenging. However, the experience of those working in the field is leading to improvements based on their practical suggestions. This manual, therefore, is a growing, evolving document. This first edition is a valuable beginning.

The current monitoring programme is aimed at developing reliable ways to gather data. The next steps would be to use those data for management. Once data are collected in a reliable uniform manner, they contribute to baselines. Provided such baselines are sensitive enough to be able to detect impacts of interventions and robust enough to support strategic planning and predictive modelling, they become powerful measures of success, indicators of where and what types of intervention are required and what adaptions are required to manage new developments.

Although measuring the litter does not make it more manageable per se, the derived data can give valuable clues, on which decisions can be made and actions planned. The WIOMSA monitoring programme and this manual are aimed at providing the tools to measure plastic waste, ultimately to set baselines against which change can be measured, and to provide the measurable foundation for management of plastic and other waste.

Dr A J Ribbink
CEO Sustainable Seas Trust and Director of the African Marine Waste Network

Chapter 1

The marine litter crisis

Danica Marlin, Toshka Barnardo & Tatjana Baleta

Chapter 1

1.1. What is marine litter

Marine litter is composed of persistent solid materials, manufactured or processed by humans, that are subsequently discarded, disposed of or abandoned, and which end up in the coastal and/or ocean environments[1]. With growing awareness of its detrimental effects, marine litter, especially plastics and microplastics, has increasingly been featured in the media and is becoming a popular topic of discussion among members of the public, scientists, and governments. Along with the effects of climate change and ocean acidification, marine litter is one of the most pressing issues threatening marine life[2]. The problem has become so ubiquitous that the focus of recent litter research has shifted from evaluating the negative effects of litter, to identifying litter hotspots, sources and pathways, and long-term monitoring of litter in efforts to reduce litter loads[3]. Additionally, there has been an increase in international, regional and national policies governing waste management, particularly that of plastic, which makes up the majority of marine litter[4,5]. However, despite the existence of these policies, marine litter persists due to a lack of synchronized global and regional strategies, and poor implementation and enforcement of existing regulations[6,7].

In this document, we use the term 'litter' to refer to discarded processed/manufactured items (including plastic, rubber, metal, paper and processed wood, textiles and glass) that are likely to end up in the marine and coastal environments. To avoid confusion, synonyms such as 'debris', 'trash' and 'rubbish' are not used in this document.

1.2. Sources and pathways of marine litter

The first step in managing the growing problem of marine litter is to stop litter entering the environment at source on land. It is environmentally and economically more sustainable to deal with litter on land and in rivers before it gets to the sea[3]. A large portion (about 80%) of marine litter comes from land-based sources[4,8]. In this context, sources refer to activities and/or sectors of society or industry which contribute to the accumulation of litter in the environment[6]. Land-based sources of marine litter include: unprotected landfills and dumpsites; sewage overflow; public littering; improper disposal of litter; industrial and urban inputs; daily activities of farming, mining and forestry; accidental loss of litter; and extreme events[6,9] (**Figure 1.1**). Litter can be transported into rivers and storm-water drains, and eventually into the sea, either through direct dumping or by means of wind, rain, snowmelt and tides[6,8,9,10]. Litter can be transported far offshore by rivers with high flow rates and strong currents while small rivers with weak currents act as litter sinks[9].

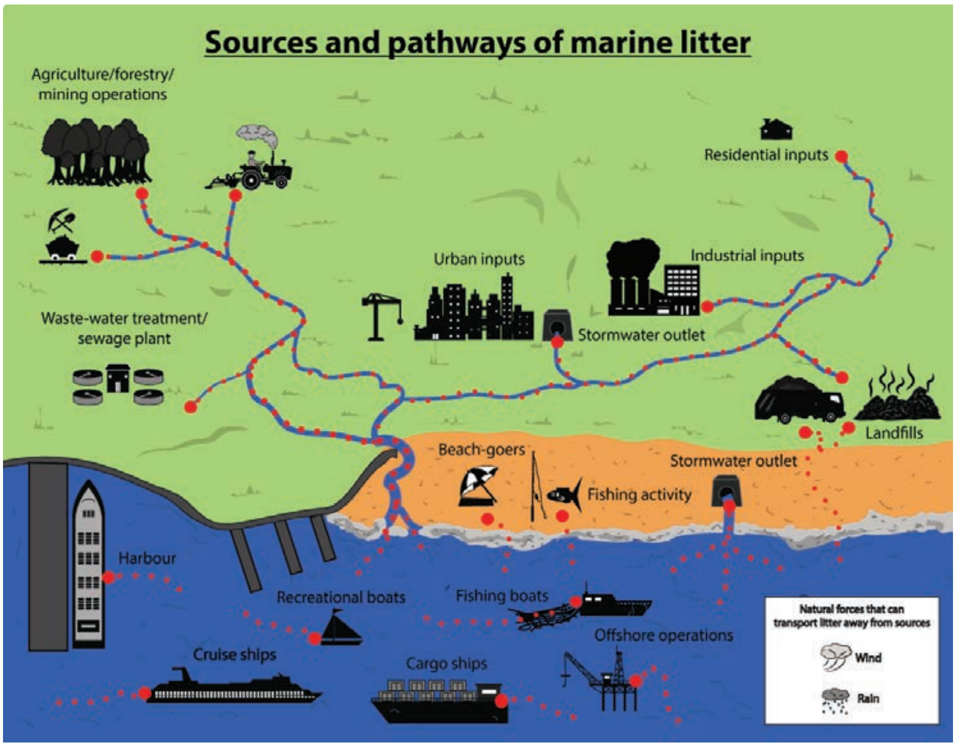


Figure 1.1: Schematic drawing of potential sources and pathways of marine litter. Litter is indicated with red dots.

The amounts and types of litter found in the open ocean and along shorelines are influenced by various factors, including distance from urban and recreational areas, shipping routes, fishing zones, climate, and ocean currents and tides[9]. The amounts of litter items, particularly plastics, along shorelines tend to increase closer to urban centres, suggesting that local sources are major contributors to marine plastics, with limited dispersal of land-based plastics from these centres[11]. The proportion of litter that returns to shores near urban centres, after entering the sea via storm water outlets and river mouths close to these cities, is affected by the characteristics of the litter item (e.g., size and buoyancy) as well as the environment into which it enters (e.g., wave action, currents or river strength upon entering the sea[11]). However, large amounts of litter have been found on inaccessible shorelines on isolated islands too far from urban centres to have floated there, suggesting that fisheries and shipping are responsible for litter in those parts[12].

Once litter enters the ocean, its sources are difficult to determine. Vessels of all types (recreational, commercial, fishing, platforms for offshore operations) are guilty of littering the sea[4]. This is in contravention of the International Convention for Prevention of Marine Pollution[13], which prohibits the discharge or intentional dumping of persistent waste into the sea, including from all types of sea vessels and stationary platforms. Despite this accidental losses and illegal dumping do still take place[12,14,15]. Additionally, under Annex V of MARPOL which came into effect in 1989, ships weighing less than 400 GT need not keep records of their waste management. Consequently, the majority of the global fishing fleets still discard all waste into the sea[16]. Due to the sheer vastness of the seas, it is difficult to monitor how much litter enters the sea from ocean-based sources, and whether laws to reduce waste are adhered to. Furthermore, extensive litter monitoring and clean-up initiatives are not feasible.

1.3. A global challenge

Buoyant litter, such as low-density plastics, may be transported over international borders by wind and ocean currents, sometimes as far as 3000 km from source[17], becoming an international problem with shared responsibilities. Plastics have been found on isolated, uninhabited islands[12], the arctic[4], and even the most remote place on the planet — at ocean depths of nearly 11 km in the Mariana Trench[18].

It has been estimated that 2.5 billion tonnes of municipal litter were generated in 2010 by 6.4 billion people living in 192 coastal and island countries (93% of the global population)[8]. Of this, 31.9 million tonnes were classified as mismanaged plastic litter, with an estimated 4.8 to 12.7 million tonnes of this entering the ocean annually. These estimates are, however, being questioned [19,20,11].

Once in the ocean, portions of marine litter wash up (and often are buried) along shorelines[11], settle on the ocean floor [21,4] and even seem to 'vanish'[22]. Whilst the ocean floor is said to be a long-term sink for marine plastics[21], beaches and backshore vegetation into which litter is buried or blown, respectively, are also important sinks[11]. The amounts of micro- (<5 mm) and nano-sized (<50 µm) marine litter are difficult to estimate due to their small size, which makes them difficult to see and quantify through conventional sampling techniques, and due to their position in the water column (i.e., usually below the water surface)[23]. Much of the plastic at sea is unaccounted for and appears to have 'vanished'[22].

Plastics degrade very slowly, requiring specific conditions to do so, and therefore persist in the marine environment for decades, if not longer[17]. Degradation occurs at different rates in marine environments (i.e., beaches, water column, seafloor), because it is affected by UV radiation, temperature and wave abrasion[23]. It is not yet known whether full degradation occurs as plastic particles are broken down into ever-smaller particles, reaching nano-sizes, and nano-plastics (NPs) research is a relatively new field of study[20,24]. Plastics may therefore persist in the environment, in the form of nano-plastics, for even longer than estimated.

1.4. The need to act

Considerable publicity has been given to detrimental impacts of litter on land, and once it enters the waterways, coasts and ocean, including ecological, economic and social repercussions [4,25,26]. Ecological impacts include litter causing harm to coastal and marine life through entanglement and entrapment, ingestion, habitat destruction, exposure to dangerous chemicals and the introduction and spread of invasive species[4, 27].

Attention has also been drawn to the economic costs of marine litter through the loss of ecosystem services (including shrinking fish stocks, damaging watercraft, devaluing property and deterring tourists) and the cost of litter removal initiatives[28]. Marine plastic litter causes an estimated 13 billion USD in damage to global marine ecosystems every year[29]. Shrinking fish stocks are of particular concern in Africa because subsistence fishing is vital to people's livelihoods and food security, with more than half of daily protein intake coming from freshwater and/or marine fish (e.g., up to 60% in Ghana and 70% in Tanzania)[25]. Additionally, fishing and related activities, such as packaging and preparation, provide over 12 million Africans with income[30]. The threat to fish stocks therefore has direct, grave consequences for almost 400 million people living along the coasts of western and Central Africa alone[31].

Social costs involve diminishing aesthetics as well as the intrinsic societal and cultural values of nature. Litter can also be detrimental to human health by causing physical injuries, affecting water quality, facilitating spread of disease, and can even have a negative psychological impact[32,33,34]. With regards to plastics, it is not necessarily the plastic particles themselves that are hazardous, but rather the chemicals added to the plastic that leach out during the plastic lifecycle (from production, to use, to eventual discarding as waste and into the environment)[35]. In addition, microplastics attract and adsorb water-borne toxins that have the potential to harm humans[36]. Simulations have shown nano-plastics alter the functioning of cell membranes[37], suggesting that they could affect human body functioning[38].

1.5. Marine litter monitoring

A first step to improving litter management is to develop a litter baseline, i.e., a starting estimate of the amount and type of litter in a given study area from which future comparisons can be made. Baselines provide the foundations upon which to build litter management strategies. Once a baseline is established, monitoring can be used to determine whether litter management strategies are effective, by measuring the change in the amounts and types of litter.

Monitoring is defined as, "the repeated measurement of a characteristic of the environment, or of a process, in order to detect a trend in space or time"[1]. In the case of marine litter monitoring, litter found in marine and coastal environments is repeatedly collected, quantified (i.e., by counts or weight) and qualified (i.e., placed into defined categories), over a predetermined period. This manual provides protocols for litter monitoring in various habitats (see **Chapter 2**).

Four major questions are to be answered by litter monitoring programmes: 1) where and what are the sources of litter on land and at sea? 2) how is the litter transported from its source to the sea? 3) how much and what type of litter is there? and 4) how do the amounts and types of litter change over time?

Monitoring forms the basis of adaptive management because it facilitates tracking of trends and the detection of emerging problems and/or non-compliance with regulations[11]. Data generated through litter monitoring informs management strategies and provides a means to track the success of these strategies[39]. When assessing the efficacy of litter management strategies, it is important to consider factors that affect litter leakage into the environment, such as population growth, particularly of the middle-class[40], city development and climate change.

As most people occupy urban areas within municipal boundaries, those municipal areas in key catchments areas that drain into the sea offer excellent opportunities for development of litter baselines. For example, Algoa Bay, South Africa, is being used to develop baselines of litter loads for the Nelson Mandela Bay Metropolitan Municipality (NMBMM) area, of which the catchment drains into the bay. The NMBM serves as a model case study where litter monitoring can be used to guide and test litter management strategies because the city and its surrounding areas are large enough to represent a large coastal city in Africa, yet are small enough to be manageable.

As part of the 'Clean up NMB' initiative, Sustainable Seas Trust (SST) is surveying litter in different areas (beaches, rivers, streets) of the metro to establish a baseline of litter loads and to monitor changes to the baseline after implementing various litter management strategies. Such strategies involve public awareness campaigns, education initiatives, liaising and partnering with the local municipality, and involving interested stakeholders (e.g., schools, businesses, citizens) in cleaning selected areas.

1.6. Current situation in Africa

Most major cities and towns in Africa already generate significant amounts of litter, a large portion (4.4 million tons) of which is mismanaged and available to enter the sea[40]. These include major cities on the mainland coast of eastern Africa (e.g., Beira, Dar es Salaam, Mogadishu, Maputo and Mombasa), western Africa (e.g., Accra, Abidjan, Dakar, Lagos, Luanda), northern Africa (Alexandria, Algiers), and southern Africa (Cape Town, Durban, Port Elizabeth; **Figure 1.2**).

Five African countries are ranked amongst the top 20 countries producing the most mismanaged plastic waste by mass; Algeria, Egypt, Morocco, Nigeria, and South Africa are estimated to contribute between 0.05 and 0.39 million metric tons of marine plastic litter per year[8]. With improved health services, the rate of population growth in Africa exceeds that of any other continent[25,40,41].

Rapid population growth, high urbanization rates, rapid economic development and increased per capita consumption all predict an overwhelming increase in litter loads in Africa if litter collection and management systems are not geared up to cope with these changing circumstances[8,25].

Currently, municipalities in developing countries tend to spend 20–50% of their budget on solid waste management[42], which is insufficient to provide waste removal services to all communities[25].

Estimates show that the current (2020) per capita waste generation (kg/person/day) in sub-Saharan Africa is 0.6 (compared to 1.3 in Europe and Central Asia), and by 2050 this will almost double to 1.1 (compared to 1.5 in Europe and Central Asia)[43]. At this rapid rate of increase, waste generation in Africa is unlikely to stabilize before 2100.

Figure 1.2: Many African countries already generate large amounts of waste, much of which is mismanaged. The amount of waste is only expected to increase with rapid population and economic growth. A) Nairobi, Kenya B) Durban, South Africa.

In efforts to combat the litter crisis, many African countries have become signatories to several international treaties regarding the regulation and reduction of marine litter, including the UN 2030 Agenda for Sustainable Development[44] and MARPOL.

The two main treaties governing African seas are the Abidjan Convention, which is officially known as the Convention for Cooperation in the Protection, Management and Development of the Marine and Coastal Environment of the Atlantic Coast of the West, Central and Southern Africa Region, and the Nairobi Convention.

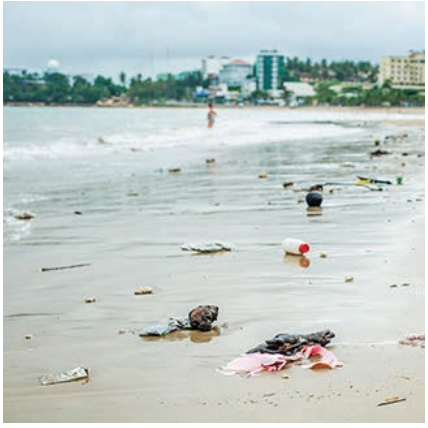
The Sustainable Development Goals (SDGs) of the UN address marine litter and pollution targets through Goal 14 (target 14.1), with a particular focus on sources from land-based activities. Other goals that incorporate marine litter and pollution are goals 6, 8, 9, 11 and 12, which target untreated wastewater (6.3), resource efficiency (target 8.4), infrastructural development (target 9.4), municipal and other litter management (target 11.6), environmentally sustainable management of chemicals and litter (target 12.4), and overall litter reduction (target 12.5).

To effectively manage litter in Africa, quantitative data are required to determine litter baselines and to monitor changes in litter loads after various management interventions[1]. Currently, data on litter production and mismanagement is not readily available for most African countries[25,40,45].

Precise data regarding litter loads, location and composition, as well as the flow from source and the amount of litter entering the sea, are rarely available. Nearly all data on African countries are based on presumed correlations with population size, demographic patterns, socio-economic information and other surrogates, with very few direct measurements made to determine actual values[25]. There is therefore a need to determine litter baselines and to monitor changes in litter loads over time, in Africa.
Many organizations have developed methods for litter monitoring[46,47,48,49]. However, due to the diversity of methods used, it is often difficult to compare data and results.

Consequently, comparing and contrasting litter loads between regions is complicated, and this impedes the development of regional and global strategies[50]. Additionally, the quality of data is compromised if monitoring is conducted by surveyors who do not have prior training. This is particularly important in Africa, where monitoring may be done by citizens with varying levels of education.

Furthermore, any litter monitoring programme that is to succeed in producing comparable data in Africa, must account for the differences in resources between countries. There are currently no harmonized litter monitoring methods that consider the varying levels of education and resources in Africa, making this African Marine Litter Monitoring Manual essential if we are to have reliable and accurate data for litter loads in Africa.



Chapter 2

A guide to litter monitoring in Africa

©John Kieser

Toshka Barnardo & Tatjana Baleta

Chapter 2

2.1. African Marine Litter Monitoring Manual

It is widely recognized that there is a need to harmonize litter monitoring protocols to enable regional and global data comparisons, identify global trends in pollution, and inform appropriate litter management strategies[1,2]. The goal of this manual is to provide a simple, reliable guide for litter monitoring in Africa and beyond. Particular attention has been given to ensure that methods are scientifically robust, feasible, and reproducible, even with limited resources and experience. The manual will therefore arm any person with an interest in assessing the origin, abundance, composition, distribution, and pathways of plastic litter in the marine environment, with the appropriate knowledge to evaluate these factors and to monitor how these change over time.

This manual presents protocols for the monitoring of litter >2 mm, in various environments and habitats. There are numerous ways in which to monitor litter in different environments (e.g., shorelines, rivers, on land[1,3]). The suitability of each method depends on, for example, the research question at hand, the feasibility of the techniques, and local conditions. It is important therefore to thoroughly consider various aspects to plan the way forward for a monitoring project before selecting sampling techniques or commencing with any surveys. Examples of aspects to consider include:

1. What is the mandate and specialization of your organization?
2. What are you hoping to achieve by conducting litter surveys?
3. What are your team's core competencies?
4. Given your research questions and available resources, what are the research areas that your team can practically embark on?
5. Given your strengths and weaknesses, how should you plan your project?

Since it is impossible to provide protocols suited to all conditions and requirements, this manual uses an ongoing litter monitoring programme in the Western Indian Ocean region as a model to highlight examples of monitoring objectives, outcomes and specific research questions, and provides monitoring techniques, which will aid in meeting these specific objectives. Note that these protocols may also be used and adapted to meet objectives and answer research questions not mentioned here.

2.2. WIOMSA Marine Litter Monitoring Programme

The Western Indian Ocean Marine Science Association (WIOMSA) has partnered with the Sustainable Seas Trust (SST) and its African Marine Waste Network (AMWN) programme to initiate an observation and monitoring system for marine litter in Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and Tanzania. This programme focuses on developing monitoring programmes mainly from land-based sources of litter. The primary goals of the programme are to determine litter baselines, identify litter sources and problem items, guide litter management strategies, and monitor the efficacy of interventions by monitoring litter over time.

Monitoring efforts for the WIOMSA Marine Litter Monitoring Programme are currently focused on litter >25 mm, since it is easier to detect, remove, study, and manage than smaller items. Furthermore, the collection and analysis of large litter usually do not require specialized techniques, equipment, or extensive training[1] and this size group is subsequently cheaper and easier to study than smaller items. Additionally, if pollution presented by these larger litter items can be curbed, then it will directly influence the occurrence of smaller fragments of litter in the environment, since a large portion of litter <25 mm originates from the degradation and fragmentation of larger items[4].

2.2.1. Objectives and outcomes

Objectives and outcomes of the WIOMSA Marine Litter Monitoring Programme include the following:

1. Determine a litter baseline

The first objective is to gather data to develop a baseline of current litter loads on land, in rivers, and washing up on shorelines in cities bordering the Western Indian Ocean. A baseline provides an indication of the initial state against which future change can be measured (for example, an increase or decrease in litter)[5]. The number of surveys required to estimate reliable baselines depends on the level of change one wants to detect and the confidence level with which this is done. For example, assuming the same confidence level, fewer surveys are required to detect a litter reduction of 90% than a litter reduction of 10%[5]. Therefore, if one wishes to be able to detect the impact of small interventions or small changes in the amount or types of litter, then detailed baselines are needed to account for seasonal and random variation in litter loads. However, if the impact of large interventions or large changes in litter loads are of interest, then detailed baselines are not as important and fewer surveys are needed.

For regions where litter data are limited, three years should prove sufficient to determine litter baselines[5]. However, at present, the WIOMSA monitoring programme is scheduled to run for the next three years only, and a primary focus of the programme is to rapidly reduce litter loads. It is not possible therefore to conduct a baseline survey without intervention for the entirety of the three-year programme. A single year will therefore be used as a baseline to compare with subsequent years, with each succeeding year providing further data. This will allow for the inclusion of seasonal data (where surveys are conducted quarterly) and will allow rapid intervention and evaluation of the efficacy of intervention methods. It should be noted that the results generated by this three-year monitoring programme can serve as a baseline for future studies in the region.

2. Identify hotspots and sources

Hotspots where large amounts of litter accumulate, can be identified by comparing amounts of litter in various places. Litter hotspots make good long-term monitoring sites to evaluate the efficacy of litter management strategies. For example, cleaning and monitoring a known illegal dumping site can provide insight into whether public awareness campaigns in the community have been successful in discouraging illegal dumping. Obvious hotspots are poorly managed landfills or illegal dumpsites. Various studies have also found higher litter loads in and around urban areas[3].

Knowledge of the source of litter provides valuable information, which can be used to identify locations and major players that need to be targeted in a litter-minimization strategy[6,7]. The source of litter is defined here as the location from where the litter is derived locally (e.g., litter coming from beachgoers, schools, retail centres, ships etc.), or on a global scale (e.g., the country of origin for beach litter). Local sources of litter can be determined by examining the litter itself to ascertain its origin (e.g., items such as wooden crates and large fishing nets that wash up on beaches, likely originate from ships) as well as by examining land-use and anthropogenic activities surrounding the sample area (e.g., a nearby river flowing through a settlement could be the source of beach litter). Brand audits provide a means of determining in which country litter was discarded or littered.

3. Develop a litter management strategy

The data that is gathered informs decision-makers and defines which are the appropriate strategies necessary to manage litter at source. While clean-up activities are important, more attention should be paid to preventing litter from entering the environment in the first place[6]. This could include a combination of legally imposed compliance (in some cases development of new policies and regulations may be required) with actions at source (such as awareness, education and consumer behaviour modification initiatives) to prevent the flow of litter to the marine environment[6]. Strategies must be linked to clear outcomes as well as have built-in metrics to evaluate their success. The SMART framework (an acronym for Specific, Measurable, Assignable/Achievable, Realistic and Time-related) provides a useful guide to setting goals when developing a marine litter management strategy[8].

4. Measure change in litter over time

Once a baseline has been determined, change in litter over time can be measured by regularly sampling in a uniform manner at selected study sites over an extended period. It should be noted that changes in abundance may not be very informative, unless surveyors understand the litter turnover rate at the study site (i.e., the rate at which litter is deposited and removed from the site). Litter turnover rates are hard to quantify because they are influenced by various factors (e.g., type of litter material, recent weather conditions, the proximity to landfill sites, formal or informal clean-up efforts, and changes in human activities over time). It is therefore recommended to measure instead the change in litter flux over time: i.e., the amount of litter entering a habitat over a given time period[3]. Accumulation surveys provide measures of litter flux by estimating the amount of litter accumulating at a study site over a given period[3].

5. Is the strategy working?

After developing and implementing an appropriate marine litter management strategy, continuous regular litter monitoring can be used to determine if the strategy is successful or if it needs to be adapted (**Figure 2.1**)[6]. Simply measuring changes to the quantity of litter at selected sampling/survey sites over time without considering changes elsewhere could be misleading. It is necessary, therefore, to quantitatively assess impacts of weather (particularly rainfall), changes in local population size, number of visitors to survey areas, changes in policy and/or enforcement, and industrial or other developments.

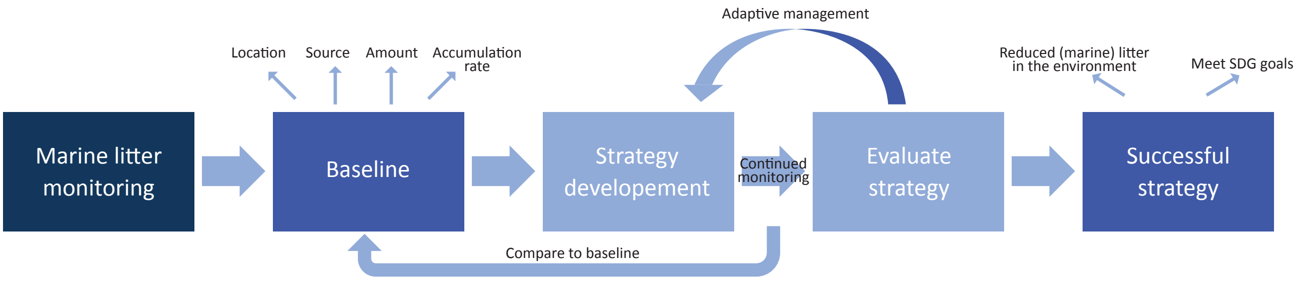


Figure 2.1: Marine litter monitoring forms the basis of an adaptive management approach to reduce litter and achieve Sustainable Development Goals (SDGs).

2.2.2. Potential research questions

Since monitoring protocols are goal dependent, it is necessary to consider what questions need to be answered when designing a marine litter monitoring programme. Depending on the questions asked, the type and quantity of data obtained and the way they are collected will differ.

Examples of questions:

1. Where are the litter 'hotspots' or areas where litter is most prevalent?
2. How much litter occurs on the shores and in the waterways of the study sites?
3. What is the composition of litter in terms of material type (e.g., plastic, paper, glass, etc.)?
4. What are the principal sources of litter?
5. What are the transport pathways that litter follows from sources to coastal and marine environments?
6. Does the amount of litter vary spatially and/or temporally?
7. What other variables affect the input of litter into marine systems (e.g., changes in wealth, increases or decreases in municipal services, weather, economic activity, education)?
8. When and where should litter traps, booms or other litter collection systems be used?
9. How effective are litter traps, booms or other litter collection systems in removing litter from waterways?

2.2.3. Sampling schedule

It is important to determine the intended monitoring period of the entire study and the frequency with which monitoring should be undertaken. Longer monitoring periods (e.g., five years and longer) provide comprehensive data in which confidence can be developed while avoiding data influenced by random events[5]. However, extended monitoring periods are only possible with adequate funding, support and commitment from institutions and individuals involved, and must have quality control measures in place to keep data collection protocols constant over time despite the potential for personnel turnover. Additionally, care must be taken to account for other changes that may occur over time that could affect litter abundance (e.g., rate of urbanization and population changes). This depends on the questions the data must answer and will influence the kinds of models that can be extrapolated from the data.

In addition to the monitoring period, a suitable monitoring frequency must be developed to collect appropriate and accurate data. Continuous and frequent sampling of macro-plastics provides the most comprehensive results but is usually not feasible (e.g., where resources are limited). Meso-plastics (plastic litter between 2 mm and 25 mm) buried on sandy shores do not require frequent sampling as amounts remain relatively constant over decades[9]. In general, sampling should occur often enough to incorporate seasonal and other variations (e.g., changes in rainfall, which may affect litter abundance at a given point in time). To fulfil marine litter monitoring objectives as stated above, macro-litter surveys should be conducted at least quarterly (i.e., every three months).

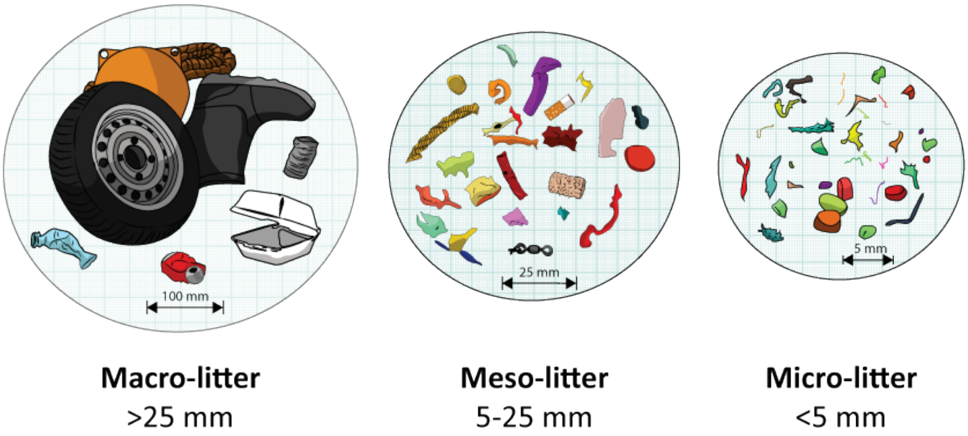


Figure 2.2:
Litter classifications by size categories.

2.3. Litter classification

Macro-litter is defined as pieces >25 mm, meso-litter as 5–25 mm, and micro-litter as <5 mm, in their longest dimension (**Figure 2.2**).

2.4. Layout of the manual

Litter can be found and studied in various environments and habitats around the world[1,3,10]. This includes habitats at sea, in inland water sources, on land, and through interactions with biota. At present, this manual provides protocols for seven types of surveys in five different habitats (**Table 2.1**). Protocols for litter monitoring in other habitats will be explored in future editions of this manual.

2.5. Guidelines for selecting sampling protocols

Sampling protocols need to be adaptable for different circumstances. Unique research questions, available resources, and level of pollution at the study site will determine how applicable and feasible various steps of the protocols are to surveyors. To promote flexibility of sampling protocols, three basic approaches are given to serve as guidelines on how the protocols can be adapted – a Gold, Silver and Bronze Standard to sampling.

The recommended minimum requirements for reliable surveys are provided in the Bronze Standard approach, while the preferred methods are highlighted in the Gold Standard approach. The Silver Standard represents an intermediate option. Protocols are flexible within the range between the Gold and Bronze Standards. A table is provided to guide surveyors in selecting an appropriate sampling approach, based on the amount of resources available (this can include number of volunteers, time, funding, and/or equipment; **Table 2.2**).

Protocols can be adapted at the discretion of the surveyors to answer specific research questions. Surveyors should use their discretion to determine which aspects of the protocols may not be feasible given the pollution level at the study site. For example, where the Gold Standard may require a study site length of 500 m, it may be more feasible, given the available resources, to sample a smaller study site at a very polluted site.

Table 2.1: Examples of habitats where litter monitoring can be conducted. This manual presents protocols for seven types of surveys in five different habitats.

	Habitat to survey	In this manual	Page
At sea	Along shorelines (beaches & rocky shores)	**Chapter 3:** Macro-litter	17
		Chapter 4: Meso-litter	32
	Mangroves	**Chapter 5:** Macro-litter	42
		Chapter 6: Meso-litter	57
	On the seabed	-	-
	Water column and surface	-	-
Inland water sources	Water column and surface of river/estuaries	**Chapter 7**	67
	River/estuary bed	-	-
	Water column and surface stagnant water	-	-
	Stagnant water bed	-	-
On land	Street surveys	**Chapter 8**	84
	Non-linear terrestrial habitats (e.g., public parks, parking lots, schools)	**Chapter 8**	84
	Stormwater channels	-	-
	Stormwater outlets	-	-
Interactions with biota	Ingestion, entanglement, bio-fouling, etc.	-	-

Table 2.2: To allow flexibility of sampling protocols, we provide three basic approaches to conducting surveys in various habitats.

	Gold Standard	Silver Standard	Bronze Standard
Resources available	Sufficient	Moderate	Limited
Recommended for	Academic institutions	Businesses & governmental organizations	Citizen scientists & non-profit organisations

2.6. Quality control

High-quality data must be collected for comparative results and to develop accurate baselines for litter monitoring. Quality control measures should therefore be incorporated into survey procedures to minimize uncertainty regarding the protocol and to ensure that data collection protocols are followed correctly. Bias during marine litter monitoring may be encountered during various stages of a survey, including:

1. **Planning stage** – e.g., site selection bias. There may be a bias towards selecting easily accessible beaches or heavily polluted beaches.
2. **Sampling stage** – e.g., uncertainty regarding study area boundaries or sample collection protocols may result in the use of different methods between surveys.
3. **Litter processing stage** – e.g., uncertainty regarding the categorization of litter may result in items being categorized incorrectly, which will make it difficult to compare datasets and results with other studies.

To reduce biases during the planning stage, we have provided clear study site requirements for each survey. Surveyors are encouraged to survey several study sites which may vary in terms of major land-use type, accessibility, proximity to potential sources of litter, and site characteristics (e.g., dominant substrate type, slope etc.). Study site description datasheets are provided to record such variations in site condition that may influence litter loads.

Special efforts have been made to make the protocols as clear and concise as possible to ensure that they are easy to follow. This includes the use of pictures and diagrams for clarification. Visual guides and guidelines for litter categorization are provided to reduce uncertainty during the litter processing stage. In addition to this, instructional videos are in development for each protocol and will soon be accessible on the Sustainable Seas Trust YouTube channel.

Regardless of steps taken to promote quality control, some bias may still occur in the form of observer bias. For example, observer bias may cause dull-coloured plastics to be overlooked in favour of brightly coloured plastics during sample collection. The best way to ensure data quality control for comparable results is to ensure that field personnel are properly trained. This responsibility falls to the lead surveyor or the organization conducting the monitoring. Additionally, to ensure continuity among data collectors at a given site, it is recommended to have at least one experienced team member who has previously conducted a litter survey at that site. If possible, the same team should be used for each survey.

2.7. General precautions/ safety measures

When undertaking litter monitoring surveys, it is paramount to ensure the safety of surveyors in the field. A few general precautions to practise include:

1. All surveyors should wear appropriate clothing and gear. These may include (but are not limited to) protective gloves, closed shoes, and sun hats. Safety or 'high visibility' vests may be required when working near traffic.
2. Carry sufficient drinking water and an adequate first aid kit when in the field. Preferably, a qualified first aider needs to be included in the survey team. Possible first aid emergencies could include cuts and abrasions, animal bites or stings, and heat stroke.
3. Check the weather and, where relevant, tidal charts before going into the field. Surveys should not be conducted in extreme weather conditions.
4. Ensure the team has all necessary permission or permits to enter an area of land (for example, private land or a nature reserve), waterways and/or intertidal zones to perform surveys and collect samples. Permits may be required to collect soil samples (required for meso-litter surveys) in mangroves and other protected habitats.
5. Undertake monitoring in pairs and/or groups and remain aware of your surroundings.
6. Notify a third party of the expected return time from the field and inform them when the team returns.
7. It is recommended to carry a means of communication (e.g., cell phone) to notify third parties in the case of an emergency in the field.
8. Do not touch or lift large, heavy, or potentially hazardous items. The appropriate authorities should be notified of potentially hazardous items.
9. At sites with large tidal ranges, or where the high tide extends to the back of the study area, it is recommended to sample 1 h after high tide to avoid being trapped by the tide.
10. Ensure monitoring does not damage the environment or disrupt local flora and fauna, especially endangered species.

Chapter 3

Macro-litter monitoring along shorelines

Toshka Barnardo, Lorien Pichegru & Peter G Ryan

Chapter 3

3.1 Introduction

Shoreline ecosystems such as beaches are among the easiest and most convenient habitats in which to monitor marine litter[1,2]. These interfaces between ocean and land are more accessible than other habitats (e.g., seabeds), often contain high quantities of litter, and require very little training and specialized equipment to monitor macro-litter[1]. Moreover, shorelines are close to land-based sources of litter, allowing surveyors to determine the sources of marine litter and guide litter reduction initiatives to stop litter at source on land. Examples of shoreline habitats include rocky shores and various types of beaches. Sandy beaches are used here as an example to outline the protocols for macro-litter monitoring along shorelines.

There are two primary approaches to monitoring macro-litter on beaches – standing-stock surveys and accumulation surveys[2,3]. For standing-stock surveys, litter is tallied and categorized within transects to determine the density of litter present at a single point in time. The interpretation of results from standing-stock surveys is complicated by the fact that the amount of litter on a beach depends on litter turnover rates that are influenced by various factors, such as local currents and circulation patterns, beach dynamics, recent weather conditions, the proximity to landfill sites, formal or informal clean-up efforts, and changes in human activities over time[3]. Standing-stock surveys are therefore helpful to identify litter hotspots and to monitor changes in macro-litter composition over time but are not sensitive enough to monitor temporal changes in abundance of macro-litter[2]. Where the goal is to assess the amount, changes in the amount, and the potential sources of macro-litter at sea (e.g., as a proxy for land-based emissions), accumulation surveys are recommended over standing-stock surveys.

Macro-litter accumulation shoreline surveys assess the quantity (count and/or weight) and type of macro-litter accumulating on a shoreline during a predetermined study period[2]. Data from accumulation studies can be used to assess the flux of litter and changes in litter loads onshore and at sea. In comparison to standing-stock surveys, accumulation surveys require more time, effort and money. However, where feasible, accumulation surveys are preferred over standing-stock surveys, as they demonstrate unambiguous trends of the flux of macro-litter onto the shoreline over time[2]. This chapter outlines the protocols for accumulation surveys and shows how these can be modified to conduct standing-stock surveys.

3.2 Site selection criteria

1. Description of study site – Macro-litter surveys along shorelines are conducted along a predetermined length of shoreline (e.g., beach or rocky shore) parallel to the ocean. The study area extends from the edge of the water to the back of the beach/rocky shore.

2. Safety precautions and consideration for natural ecosystems – Surveys should not be conducted at sites where sampling may pose a risk to surveyors, nor where there are endangered or protected habitats and species (e.g., nesting turtles). Surveys should not disrupt or harm natural ecosystems. Where possible, surveyors should avoid raking beaches or removing natural organic matter such as seaweed, as this may be harmful to the organisms naturally occurring on the beach. Other actions such as trampling dune systems should also be avoided.

3. Access to sites – Sites should have clear, year-round access for surveyors. Sites with limited or no access to the public are ideal, as these provide a controlled site without public interference (i.e., littering or cleaning) to assess litter on the shore.

4. Clean-up activities by third parties – No regular public clean-up activities should take place at the study site. If potential sites are regularly cleaned, surveyors should make the appropriate arrangements with local authorities to ensure that study sites are not cleaned during an accumulation study.

5. General site characteristics required:

- Sites should have sand, gravel, or other substrates where litter can accumulate.
- Low to moderate slopes (15–45°) are required for litter to accumulate.
- Sites should be exposed to the open sea. Breakwaters and jetties may influence water circulation and associated litter loads.
- Sites where the shoreline is being eroded or cut back should be avoided as buried litter is exhumed in this process, which biases estimates of new litter accumulation.
- Sites where river streams are close to the sampling area should be avoided, since accumulation surveys are concerned with litter washing up from the ocean. Litter flowing down the river will thus bias estimates of litter washing up with the tide.

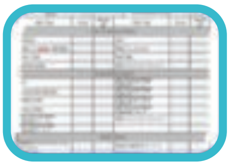
6. Study site dimensions – The recommended study-site length is 100 m for standing-stock surveys, and 600 m (a 500 m transect with 50 m buffer zones on either side) for accumulation surveys. It may be necessary to adjust the length of the study area based on the available resources of the surveyors and the pollution level at the site. Study-site length is therefore flexible and may be decided at the discretion of the surveyors. Guidelines for selection of study-site length and other important factors are provided in **Table 3.2**.

7. Study site selection – Several sites should be chosen for comparison, in accordance to the specific question to be answered. Random site selection may not be possible, as sites will likely need to vary in proximity to a landfill, to urban areas, commercial areas, industrial areas, etc., depending on the research question. In such instances, site selection should be guided by knowledge/expectations of the amount and type of litter that may be found at a site (based on the factors mentioned above), without first visiting the site to investigate litter loads. Ideally, all study sites should be sampled simultaneously (on the same day), or at least during a small temporal window.

> *Please contact SST if there is any uncertainty regarding the study site requirements.

3.3 Equipment list


1. Writing equipment and clipboards


2. Datasheets


3. Demarcation flags/signs


4. Camera


5. GPS device or cellphone


6. Measuring tape (50 m)


7. Work gloves


8. Bags/containers to collect litter


9. Environmentally friendly paint/markers


10. Bucket & clean brush


11. Scales (0.1 g & 1 kg resolution)

3.4 Standing-stock survey

Standing-stock surveys are conducted at a single point in time (e.g., over a single day). The protocol for these surveys is like that of accumulation surveys (see below). For differences between standing-stock surveys and accumulation surveys, see **Table 3.1**). Macro-litter (>25 mm) visible at the surface of the sand is collected, cleaned, categorized, counted, and weighed. Smaller items such as cigarette butts and caps/lids should also be included, since these are common beach litter items. Site description, site condition, brand audit (optional), and macro-litter datasheets (**Datasheets 1–4**) need to be completed for standing-stock surveys. The recommended transect length for standing-stock surveys is 100 m, but this may need to be adjusted based on the available resources of the surveyors and the pollution level at the site (see **Table 3.2**). Standing-stock surveys are recommended for riverbank surveys, as daily accumulation of litter becomes hard to quantify when litter is flushed from the banks during strong river flows.

Table 3.1: Basic differences between standing-stock surveys and accumulation surveys.

	Standing-stock survey	Accumulation survey
Removal of litter	Optional	Mandatory
Number of sampling days	1 day (normally)	10 consecutive days (recommended)
Transect length	100m	500m
Type of data that can be collected	• Litter density • Litter weight • Types of litter	• Litter accumulation rate (count & weight) • Types of litter
Advantages	Quick, easy, cheap	More reliable data

3.5 Accumulation survey

3.5.1 Protocol

The basic protocol for an accumulation survey includes an initial Day Zero clean-up of all visible macro-litter on a predetermined stretch of beach, followed by daily clean-ups of the site for 10 consecutive days. After each day, accumulated litter is collected to be cleaned, categorized into predetermined litter types (as per datasheets), and then counted and weighed. At the end of an accumulation survey, surveyors will be able to calculate the number and weight of litter accumulating per metre (m^{-1}) of beach per day. Accumulation surveys should not be conducted over spring tides, as these extreme tides may unearth buried litter on the beach and bias estimates of litter accumulating from the sea. See **Appendix 1** for a brief field guide for macro-litter accumulation surveys along shorelines.

Note that certain aspects of the sampling protocol are flexible and may be adapted to answer specific research questions and to ensure that the surveys are feasible when resources are limited. To ensure comparability of results on a large scale, guidelines are presented for adapting protocols by providing three basic approaches to accumulation surveys (see **Table 3.2**). The recommended minimum requirements for a reliable accumulation survey are provided in the Bronze Standard approach, while the recommended method is highlighted in the Gold Standard approach. Examples of study-site lengths have been provided here, but surveyors may select any alternative transect length based on their local beach characteristics, beach pollution level, and available resources. By calculating litter loads per metre of beach, surveyors can select a custom study-site length, while ensuring that results are still comparable with those of other studies.

Table 3.2: Suggested approaches for macro-litter accumulation surveys along shorelines, given the available resources at the surveyors' disposal and level of pollution at the study site.

	Gold Standard	Silver Standard	Bronze Standard
Transect length	500 m	250-500 m	250 m
Transect width	**Water's edge to the back of the beach**	**Water's edge to the back of the beach**	**Water's edge to the back of the beach**
Consecutive days of sampling	10	7–10	7
Size of litter to survey	>25 mm	>25 mm	>25 mm
Day zero initial clean-up	Yes	Yes	Yes
Litter counts	Yes	Yes	Yes
Litter weights	Yes	Yes	Optional
Weighing individual pieces of litter	Yes	No. Weight is determined per litter type (e.g., lollipop sticks)	No. Weight is determined per litter type (e.g., lollipop sticks)

3.5.1.1 Set-up at the study site

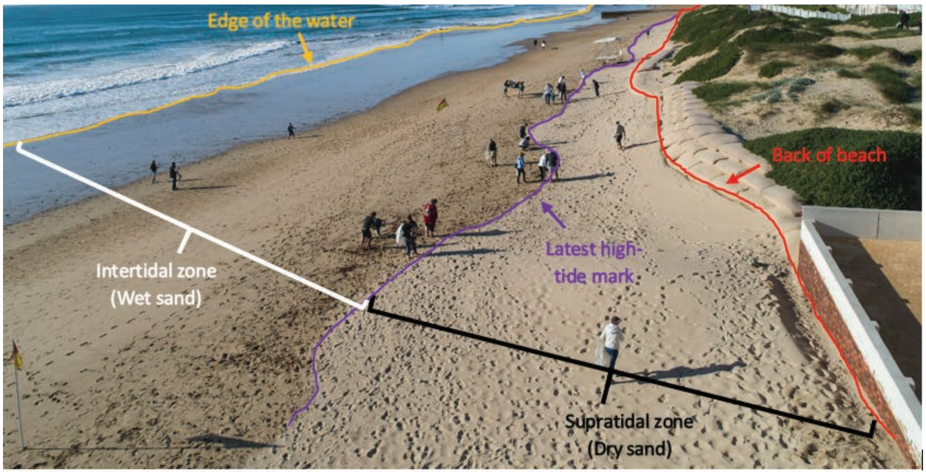


Figure 3.1: Macro-litter accumulation surveys are conducted along a predetermined length of a beach in the area that extends from the edge of the water to the back of the beach. Cleaning should extend into the back of the beach to clear any accumulated litter.

Macro-litter accumulation surveys are conducted along a predetermined length (e.g., 500 m) of a beach parallel to the water in the area that extends from the edge of the water to the back of the beach (**Figure 3.1**). The back of the beach is usually easily identifiable by the presence of cliffs, dunes, vegetation, or permanent anthropogenic structures such as roads, buildings, fences and seawalls. In some instances, the back of the beach may be identifiable by a change in dominant substrate type or topography (e.g., a substantial change in slope). Regardless, this outer boundary of the study area should be explicitly defined to ensure that all future surveys sample the same area.

It is recommended that permanent reference points (e.g., signs/markers) be established at the beginning and end of the study site to ensure that the same site is surveyed in the future. The alternative is to use GPS readings (to be recorded during site description) and local permanent landmarks (e.g., big rocks, trees, a house or structure) to locate study sites. On beaches that are open to the public, signs should be placed throughout the study area to indicate to the public (or any potential stakeholders) that a study is being conducted and that the beach should not be cleaned during the survey (**Figure 3.2**). These signs may also serve as reference points for the boundaries of the study area. The number of signs required should be determined by the surveyors and depend on the width of the study area, access points to the study area, and the number of likely visitors to the study area. When constructing signs for the study area, consider that the signs will be exposed to the elements for the duration of the survey, and that they may be stolen (and thus need to be replaced). Local municipalities and/or organizations should be contacted to ensure that no clean-ups or major public events are scheduled at the study site during the survey.

Figure 3.2: Signs should be placed throughout the study are to indicate to any potential stakeholders that the study area should not be cleaned during a survey.

3.5.1.2 Site description

Once an appropriate study site has been selected and demarcated, study-site information should be recorded (**Figure 3.3**). Please see Datasheet 1 for the information required for the study site description (e.g., GPS coordinates for the start and end of the transect, beach width, substrate type, tidal range, nearest town, etc.). This datasheet should only be completed once per survey. In contrast, daily changes in site conditions (e.g., weather and wind speeds) need to be recorded on **Datasheet 2** every time the site is surveyed. Information regarding some aspects of the site descriptions is provided below

Figure 3.3: Record the study site information in datasheets 1 & 2.

Measuring beach width

Beach width (m) is defined as the distance from the low-tide water mark to the back of the beach. This can be measured at any low tide during a survey. To determine the average beach width across the study area, the width should be determined at regular intervals along the transect and averaged. It is recommended to have at least five width measurements evenly spaced along a transect.

Calculating beach slope

Beach slope can be calculated using the horizontal tidal distance and the vertical tidal range.
Percent (%) slope is calculated as follows:

$$\textit{Slope}\ (\%) = \frac{\textit{Vertical tidal range}}{\textit{Horizontal tidal distance}}\ X100$$

The *horizonal tidal distance* is defined here as the distance from the low-tide to the high-tide water mark. The *vertical tidal range* is the vertical distance between the spring high-tide and spring low-tide water mark. Vertical tidal range can be taken from tidal charts.

3.5.1.3 Day zero clean-up/standing stock surveys

Prior to beginning a new accumulation study, all visible litter (>25 mm) on the surface or protruding from the surface should be removed from the study site in an initial clean-up event (defined here as the Day Zero clean-up). Smaller items such as cigarette butts and caps/lids should also be included, since these are common beach litter items. Litter collected during an initial clean-up of the study area can be used for standing-stock surveys, but should not be incorporated into an accumulation survey. A clean beach with zero litter is required before daily litter accumulation can be measured.

The day zero clean-up for accumulation surveys should be completed along a predetermined length of the study area, extending from the edge of the water, to the back of the beach. This area includes the transect where accumulation surveys will be conducted, as well as 50 m buffer zones on either side of the transect (see **Figure 3.4** for suggested study-site lengths). Buffer zones are included to prevent biased estimates of accumulation due to lateral drift of litter from adjacent, uncleaned areas.

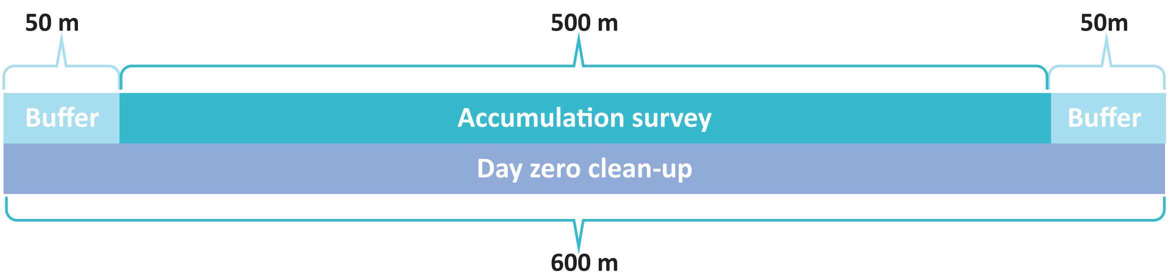


Figure 3.4: Schematic diagram indicating how a study site should be divided along its length for accumulation surveys.

Where possible, the immediate vicinity around the study area should be cleaned to ensure that accumulation estimates are not influenced by lateral movement of litter. Litter collection should therefore extend into the dunes or vegetation at the back of the beach, as these areas often act as accumulation zones for litter. It is recommended to walk in a planned pattern (to be determined at the discretion of the surveyors; see **Figure 3.5** for an example) when collecting litter. It is recommended that at least one person, 'The Sweeper', follows behind the rest of the surveyors to pick up litter items that may have been missed and ensure that the entire site has been thoroughly cleaned. It is recommended to perform a brand audit on the litter collected on Day Zero (see **Brand auditing**). If study areas are heavily polluted, brand audits can be performed on a sub-sample of the litter, e.g., for litter collected within a 100 m transect in the larger study area. Please contact SST if there is any uncertainty regarding the sub-sampling for brand audits.

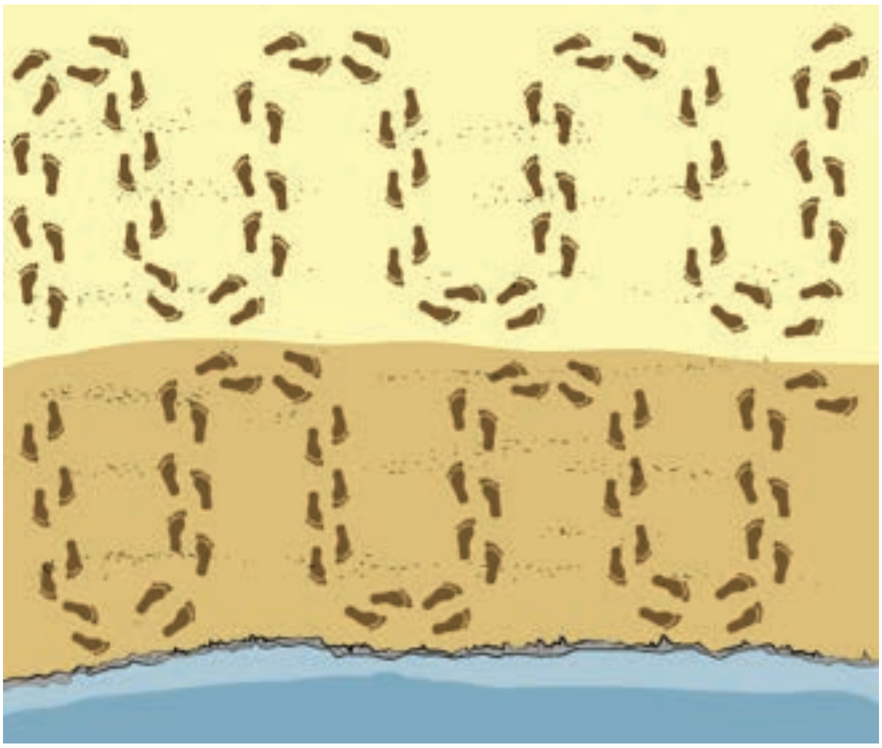


Figure 3.5:
Daily surveys of the study area should be conducted by walking in a planned pattern along the study area.

3.5.1.4 Brand auditing

By counting and categorizing branded litter found during clean-ups of polluted sites, information can be obtained regarding the type and origin of litter. Brand audits are recommended for every litter survey. Here we present protocols adapted from the '#BreakFreeFromPlastic' official brand audit protocols. '#BreakFreeFromPlastic' has developed a protocol to conduct plastic brand audits on a global scale. The coalition gathers the results of global brand audits to compile a report highlighting the brands and types of plastics commonly found at clean-ups around the world.

To maximize the impact of clean-ups, it is recommended that official brand audits are submitted to the '#BreakFreeFromPlastic' website. It should be noted that there are some key differences between the protocols presented here and that of '#BreakFreeFromPlastic'. The primary goal of brand audits in the context of this manual is to obtain information regarding the source of the litter and the persistence of litter in the environment.

The official '#BreakFreeFromPlastic' protocols have thus been modified to include all litter (as opposed to just plastic) and to only include branded items with the relevant information to answer the research questions stated above. Surveyors interested in performing the official '#BreakFreeFromPlastic' plastic brand audit should therefore visit their official website at https://www.breakfreefromplastic.org/brandaudittoolkit/ for more information and to ensure that they collect the appropriate information.

Brand audits can be performed on litter from standing-stock surveys or on the litter collected on Day Zero of an accumulation survey. To facilitate brand audits, branded and non-branded litter may be separated during clean-ups. After collection, each piece of branded litter should be counted and categorized as per the brand audit datasheet (**Datasheet 3**).

Information regarding the brand name, manufacturer, source of the litter (local or foreign), type of product, type of material, type of layers (for plastic items), and date manufactured or best before (BB) dates (when date manufactured is not available) are required for each piece of branded litter (**Figure 3.6**). Where possible, the location of sale can be recorded for receipts or other items. A visual guide (**Appendix 2**) is available to aid in identifying the type of product and packaging for each piece of litter recorded.

Figure 3.6: Information regarding the brand name, manufacturer, date manufactured, and source of the litter that can be found on branded items.

The product source is defined here as the country where the product was most likely discarded (as opposed to just the country of manufacture). Some products may be imported from foreign countries (e.g., China), then bought and thrown away locally. In such instances, especially for litter washing up on seashores, the origin of the litter is uncertain. It is necessary therefore to identify items manufactured elsewhere but sold locally. Brand audits from litter surveys on land are useful to compile a master list of branded items which are known to be sold/found locally. This list could help determine the source of litter washing up on shorelines and reduce the uncertainty and potential bias regarding the source of beach litter.

When the packaging is fragmented or stained and not all required information is visible, available information should be recorded as per the brand audit datasheet and "N/V" recorded for information not visible. Information regarding the manufacturer and source of the litter can be researched if the brand is known. Only items that include at least one of the following need to be incorporated into the brand audit: 1) brand, 2) manufacturer, 3) source of the litter, 4) date of manufacturing, and/or 5) best before date. Items without this information, therefore, do not need to be included in the brand audit.

However, if surveyors are interested in a more comprehensive survey that also includes non-branded items, then information regarding types of products and material can also be included in brand audits, even when the previously mentioned information is not available (as is the case in the official 'BreakFreeFromPlastic' brand audit).

3.5.1.5 Accumulation survey sample collection

1. Within the length of shoreline (e.g., 600 m) cleaned on Day Zero, a smaller area (e.g., 500 m) will be surveyed daily for 10 consecutive days, starting the day after the Day Zero clean-up, to collect any accumulated litter (**Figure 3.4**). Buffer zones of 50 m are maintained on each side of the 500 m transect. These buffer zones should have been cleaned on Day Zero and during the survey. Litter collected in the buffer zones should, however, not be included in the accumulation survey.

2. Daily surveys of the study area should be conducted by walking in a planned pattern (**Figure 3.5**). The entire distance between the edge of the water to the back of the beach must be surveyed. As with the Day Zero clean-up, litter collection should extend into the dunes or vegetation (or other features) at the back of the beach to clear any litter that has accumulated from the day before.

It is recommended to use a parallel walking pattern and to divide the study area among surveyors. The precise walking pattern used to survey the area is not as important as ensuring that the entire study area is surveyed thoroughly and cleared of all accumulated litter.

3. Every piece of litter encountered should be collected for analysis in the laboratory (**Figure 3.7**). In the spirit of reducing single-use plastic waste, it is recommended that, wherever possible, surveyors should use reusablebags/containers to collect daily litter.

Figure 3.7: Collect every piece of litter on the surface or protruding from the surface.

Litter (and data) should be separated into two categories:

I. Litter collected below the latest high-water mark (i.e., wet sand of the intertidal area).
II. Litter collected above the latest high-water mark (i.e., dry sand of the supratidal area).

Surveyors may experience some difficulty in distinguishing wet and dry sand during/after rainfall events. In such instances, the strandline (the line of accumulated debris and/or seaweed washed up by the tide) from the latest high tide should be used as an indication of where the intertidal area/wet sand ends. Strong winds may bury strandlines in sand and may blow litter from the intertidal zone towards the back of the beach. Surveyors should use their discretion in these instances to determine whether litter items have been washed up by the tide, in which case they should be included in the wet sand category.

Collection bags/containers should be clearly labelled to include the study site name, date of collection, and the zone of collection i.e., intertidal zone or supratidal zone.

4. If an item of litter is too large to be removed (e.g., tractor tyres or buried ropes/nets), make a clear, recognizable mark (e.g., using paint) on the item (**Figure 3.8**). This prevents the object from being counted in subsequent surveys. An alternative is to photograph it and note the locality. Heavy or large items should be recorded, counted and weighed where possible.

If items are too heavy to weigh, the mass may be estimated by 1) measuring the dimensions of the object (using a measuring tape), 2) calculating the volume of the object, and 3) multiplying volume by density of the type of material. The density of materials can be found on the internet. To facilitate mass calculations at a later stage, be sure to record the type of material alongside the type of item in the datasheet (e.g. 'Large Tractor Tyre [Rubber]').

5. Potentially dangerous items such as chemicals, weapons, and ammunition should be recorded and counted but not handled (**Figure 3.9**). The relevant authorities should be notified of any potentially dangerous items. It is recommended that the item be photographed, and the locality noted to avoid counting the object in subsequent surveys. The mass of potentially dangerous items should be estimated as previously mentioned in point 4 – estimating the volume of the object and multiplying by the density of the material. For medicines, items may be collected, and the weight estimated, but the contents should not be handled.

6. Litter that can clearly be identified as beachgoer litter (e.g., temporary picnic sites with a concentration of glass bottles and/or food packaging) should be included with litter collected on the dry sand/supratidal zone regardless of where it was found on the beach. This reduces the chance of over-estimating litter washing up with the tide.

Figure 3.8: To prevent counting the same items twice, make a clear, recognizable mark (e.g., using paint) on items that are too large to be removed from the study site.

Figure 3.9: Potentially dangerous items should be recorded and counted but not handled.

7. During an accumulation survey, litter items may be encountered that were not found during the standing-stock survey or exhumed as sand was displaced during surveys. These items were deposited before the accumulation survey began and should thus be excluded from these surveys. It may prove difficult to determine whether litter has been exhumed/missed or newly deposited. Recently exhumed items often look soiled or more degraded than newly washed up material. Surveyors should use their discretion and exclude any items that they suspect have been exhumed/missed during the standing-stock survey.

3.5.1.6 Laboratory analysis Litter processing

1. Upon returning to the laboratory, or to an appropriate location for analysis of the litter, each piece of litter must be cleaned and dried before weighing. Biological material such as animals and seaweed that may influence weight measurements should be removed during the cleaning process (**Figure 3.10**). It is recommended that each piece of litter is rinsed in a bucket of water and air-dried. Where possible, clean brushes (e.g., paintbrushes) can be used to remove sand from dry objects. Note that some items, such as sponges, are easier to clean when dry. Brushes may also be used to remove hard-to-reach sand in the folds and corners of the litter. Alternatively, packets and bags may be turned inside-out or torn carefully along the seams (without breaking the litter into more pieces) to remove sand that accumulates in the corners. Hygiene and sanitation items such as condoms, sanitary pads, tampons and diapers need not be washed or cleaned for weighing. Weights of clean, dry proxies should be used in such cases. The same applies to clothing or other fabric.

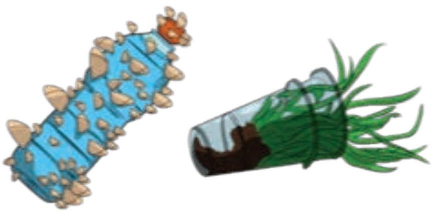


Figure 3.10: Biological material should be removed from litter during the cleaning process.

2. All pieces of macro-litter must be counted and categorized into litter types as per the litter datasheet (**Datasheet 4**). See **Appendix 3** for a visual guide to the macro-litter categories and **Box 3.1** for more information about how to process the litter after cleaning it. **Appendix 4** may be used to sort litter fragments into different size classes as required for **Datasheet 4** (**Figure 3.11**).

Figure 3.11: Appendix 4 can be used to sort litter fragments into different size classes as required.

Box 3.1. Guidelines for categorization of macro-litter

1. How to categorize fragments of litter:

If fragments are recognizable as being part of a larger item, then it should be recorded as that item. For example, if a fragment of a beverage bottle (see image) can clearly be identified as such, then it should be counted and weighed as a beverage bottle. However, if there is doubt regarding the origin of the fragment, it should be categorized as a fragment according to its properties e.g., ‘Plastic fragment – hard (2.5–5 cm)’ or ‘Metal fragment (10–25 cm)’.

2. How to count multiple fragments originating from a single item:

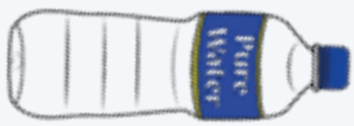
If multiple fragments have been collected that can be matched to the same origin (e.g., a single torn sweet packet), it should be recorded as separate fragments, as it would have dispersed separately if not collected. Additionally, it may be hard to keep track of litter fragments when working with large quantities of litter. However, if litter items are torn or broken during or after collection, they should be recorded as one item.

3. How to record entangled items:

If multiple items of litter are entangled, they should be untangled wherever possible and recorded separately (unless otherwise indicated).

4. How to record items consisting of multiple litter types:

Where litter items from different categories are collected as part of one entity, it should be recorded as the dominant litter type by weight. For example, if a plastic beverage bottle with a bottle cap and drink label is collected, it should be recorded as ‘Bottle – Beverage’ under the ‘Plastic Objects’ category. Similarly, a wooden beam with nails embedded will be recorded as a wooden beam.

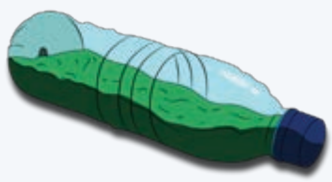


5. How to categorize an item that is not listed in the datasheet:

If an item is encountered that does not fit into a listed litter type or category, take a photograph, and describe and record it in the ‘Others’ section as ‘Item Name (Material Type)’ – for example: ‘Matchbox (Cardboard)’.

6. How to weigh items that contain liquids:

If an item contains liquids, the contents should be poured out before weighing. However, if there are safety concerns regarding disposal of the liquid, then an empty proxy of the same type of container can be weighed.



Before weighing the litter, surveyors should ensure that all items are dried properly. Items such as fabric and cigarette butts may take longer to dry. Litter should be weighed per type of litter item to the nearest 0.1 g (**Figure 3.12**). For example, surveyors may have collected 112 lollipop sticks with a total weight of 56.0 g. Some heavier items may require a different scale with a 1 kg resolution. Hooks, sinkers, lures and other fishing equipment should be removed from fishing lines and weighed in their respective litter categories.

Figure 3.12: Litter should be weighed per type of litter to the nearest 0.1 g.

Depending on the research question and the available resources, each piece of litter may be weighed individually to provide information regarding litter fragment weights. For identical complete items (e.g., earbuds), an average weight per item may be used and multiplied by the number of complete pieces. However, unique and/or fragmented items should be weighed individually when surveyors are concerned with the individual weights of items.

3. Separate datasheets need to be completed for litter collected in the intertidal and supratidal zones. This allows surveyors to estimate the amount of litter being washed up from the ocean (i.e., litter found in the intertidal zone) versus litter dumped by beachgoers (i.e., litter found in the supratidal zone). Since stranded litter may be blown into the supratidal zone, and beachgoers may litter in the intertidal zone, surveyors should use their discretion to assign such items to the correct datasheet.

4. Once the survey is complete, litter should be disposed of correctly, ideally for recycling, or stored for further analysis (**Figure 3.13**). Biodegradable organic waste can be composted, and recyclable materials can go to recycling and/or material recovery facilities.

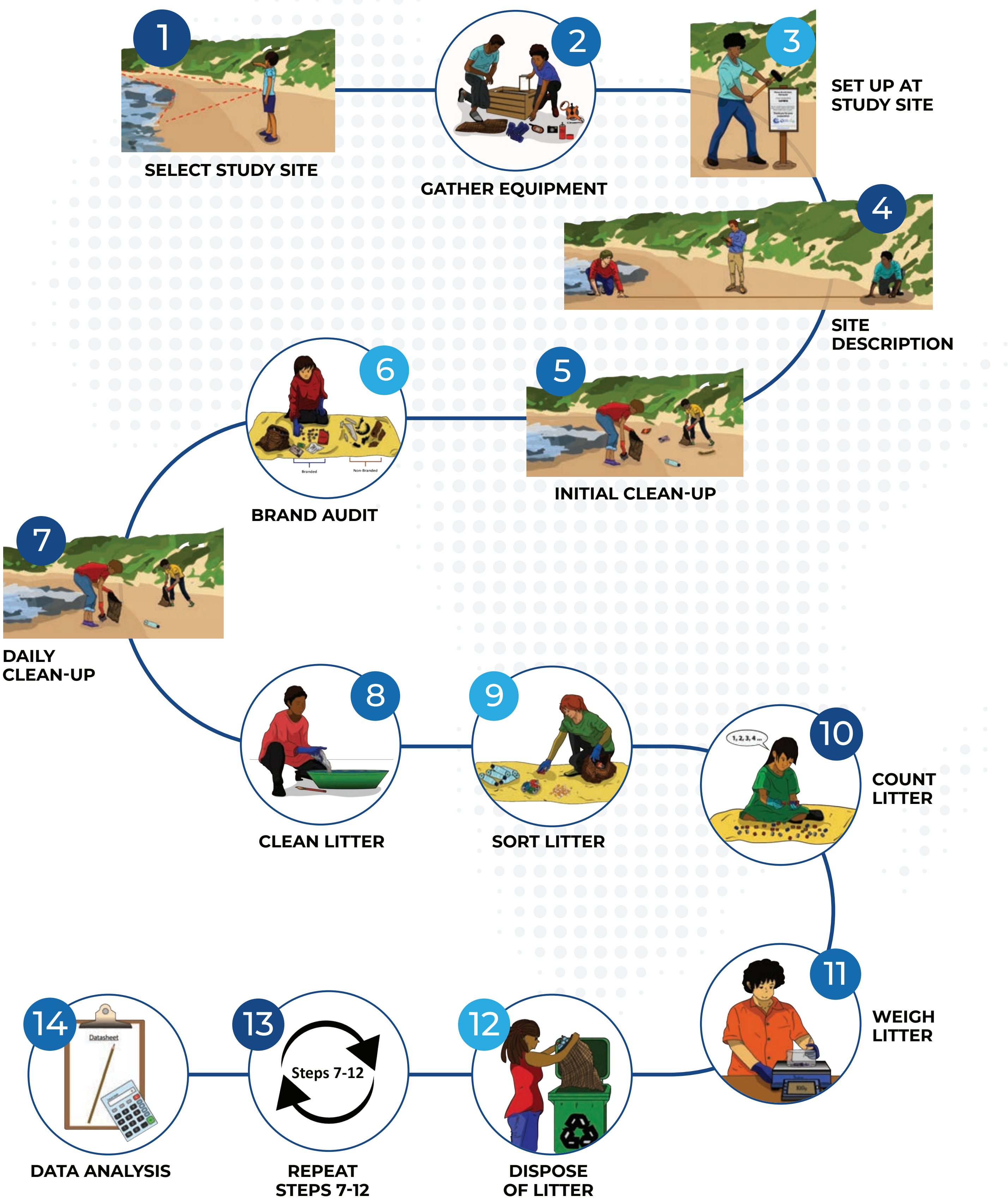

Figure 3.13: Litter should be disposed of correctly after the survey is completed.

5. For accumulation surveys, repeat the daily survey across the same stretch of beach for 10 consecutive days after the initial clean-up. Please note that new datasheets for site conditions and litter need to be completed for each day of the survey. The frequency at which surveys are conducted will depend on the research question. If the focus is on establishing litter baselines and monitoring changes over time, then quarterly surveys are recommended. If small changes in litter loads are of concern, then more frequent surveys will be necessary.

3.6 Data analysis

The total number and weight of items will be calculated per 100 metres of beach for standing-stock surveys (e.g., 5 items.100 m^{-1} and 20.0 g.100 m^{-1}) and per 100 metres of beach per day for accumulation surveys (e.g., 2 items.100 m^{-1}.day and 0.5 g.100 m^{-1}.day). For both types of surveys, this should be calculated as a total (i.e., all litter), per category (e.g., plastic), and per litter type (e.g., lollipop sticks). This will allow surveyors/researchers to compare broader results (per category and in total) between sites and over time, while also being able to detect changes in the number and weight of litter items over time. The latter is important to inform and monitor the effectiveness of litter reduction methods

Protocol for macro-litter monitoring along shorelines



Chapter 4

Meso-litter monitoring along shorelines

Toshka Barnardo, Lorien Pichegru & Peter G Ryan

Chapter 4

4.1. Introduction

Most marine plastics are destined to degrade and fragment into smaller particles[1,2]. These particles are substantially harder to manage and remove from the environment compared to larger plastic litter. Small plastic particles subsequently make up a large portion of plastics floating at sea[3], and they commonly wash up along shorelines, even on the most remote shores[4]. Various wildlife species mistakenly consume these small plastic items, with harmful consequences – including death[5].

Meso-litter are usually defined as particles between 5 and 25 mm that have been manufactured or produced by humans (e.g., plastic beads, industrial pellets, or nurdles), or that originated from the degradation and/or fragmentation of larger items of litter[6]. However, we include larger microplastics such as industrial pellets, which can be sampled using the same techniques as meso-plastics. Along shorelines, meso-litter primarily originate from the ocean, since beachgoers are unlikely to discard such small items[7]. The higher loads found near urban-industrial centres[8] suggest that meso-litter washing up on beaches come from local land-based sources, but the presence of bryozoans and other epibionts (that usually live on top of other living organisms) on many freshly stranded fragments also indicate offshore inputs.

Shoreline meso-litter surveys aim to assess the abundance and composition of meso-litter washing ashore. Meso-litter is typically concentrated in strandlines (the line of accumulated debris and/or seaweed washed up by the tide). Studies have subsequently used point sampling within a single strandline to estimate meso-litter loads[4]. However, point sampling does not provide a reliable estimate of actual meso-litter loads, since older, buried strandlines are not sampled[7]. It is recommended therefore that meso-litter is sampled across different strandlines to provide an index of the amount of meso-litter accumulating on the beach.

Once deposited by the tide, items can be buried and un-buried over time due to the dynamic nature of shorelines[8,9]. Despite this flux, abundance of meso-litter changes slowly over time, with little difference between decades[8]. Accordingly, surveys assessing the abundance and composition of meso-litter along shorelines do not need to be conducted at frequent intervals but can instead be conducted annually or less frequently.

Short-term accumulation rates cannot be estimated for meso-litter as it is impossible to completely clear a section of beach of meso-litter[7]. Meso-litter along shorelines can therefore only be surveyed by means of a standing-stock survey, which if repeated over regular intervals, can provide long-term accumulation data. It is important to note that standing-stock estimates are influenced by both the amount of litter deposited on the beach over time and the turnover rate of litter (how fast litter is removed from a site by wind, waves, or external factors)[8]. Subsequently, meso-litter loads are dependent on beach characteristics (e.g., slope and substrate type), environmental conditions, and litter input[8].

To optimize sampling effort and data collection, it is recommended to incorporate industrial plastic pellets/nurdles into meso-litter surveys. With diameters between 2 and 5 mm, industrial pellets are classified as micro-litter[6]. However, these pellets can make up a substantial portion, by count and weight, of shoreline litter smaller than 25 mm[8]. We therefore propose a protocol whereby buried litter between 2 and 25 mm is collected and studied. Within this broader size range, we have subdivided litter into different size categories to obtain information regarding average fragment sizes of litter, and to make our data comparable with a wider range of studies assessing various fragment sizes.

4.2. Site selection criteria

Meso-litter surveys can be conducted within the same study sites as macro-litter accumulation surveys (**Chapter 3**). Site selection criteria for meso-litter surveys may therefore be the same as for macro-litter accumulation surveys and include the following:

1. **Description of study site** – Shoreline meso-litter surveys are conducted in a predetermined area (strip transect) that extends from the most recent strandline to the stormwater strandline.
2. **Safety precautions and consideration for natural ecosystems** – Surveys should not be conducted at sites where sampling may pose a risk to surveyors and/or where there are endangered or protected habitats and species (e.g., nesting turtles).
3. **Access to sites** – Sites should be readily accessible to surveyors.
4. **General site characteristics required**
    - Sites should have sand, gravel, or other substrates where litter can accumulate.
    - Low to moderate slopes (15–45°) are required for litter to accumulate[11].
    - Sites should be exposed to the open sea. Breakwaters and jetties may influence water circulation and associated litter loads.
    - Sites should have undisturbed beach strandlines.
5. **Study site selection** – Several sites should be chosen for comparison, in accordance to the specific question to be answered. Random site selection may not be possible, as sites will likely need to vary in proximity to a landfill, to urban areas, commercial areas, industrial areas, etc., depending on the research question. In such instances, site selection should be guided by knowledge/expectations of the amount and type of litter that may be found at a site (based on the factors mentioned above), without first visiting the site to investigate litter loads.

4.3. Equipment list


1. Writing equipment and clipboards


2. Datasheets 1 & 5


3. Demarcation flags/signs


4. Camera


5. GPS device or cellphone


6. Measuring tape (50 m)


7. Work gloves


8. Bags/cotainers to collect litter


9. Stackable test sieves OR 50 x 50 cm framed sieves with mesh sizes of 2 mm & 25 mm


10. Small hand spade


11. Scale (1 mg resolution)


12. 20 Litre bucket


13. Bucket and clean brush

4.4. Protocol

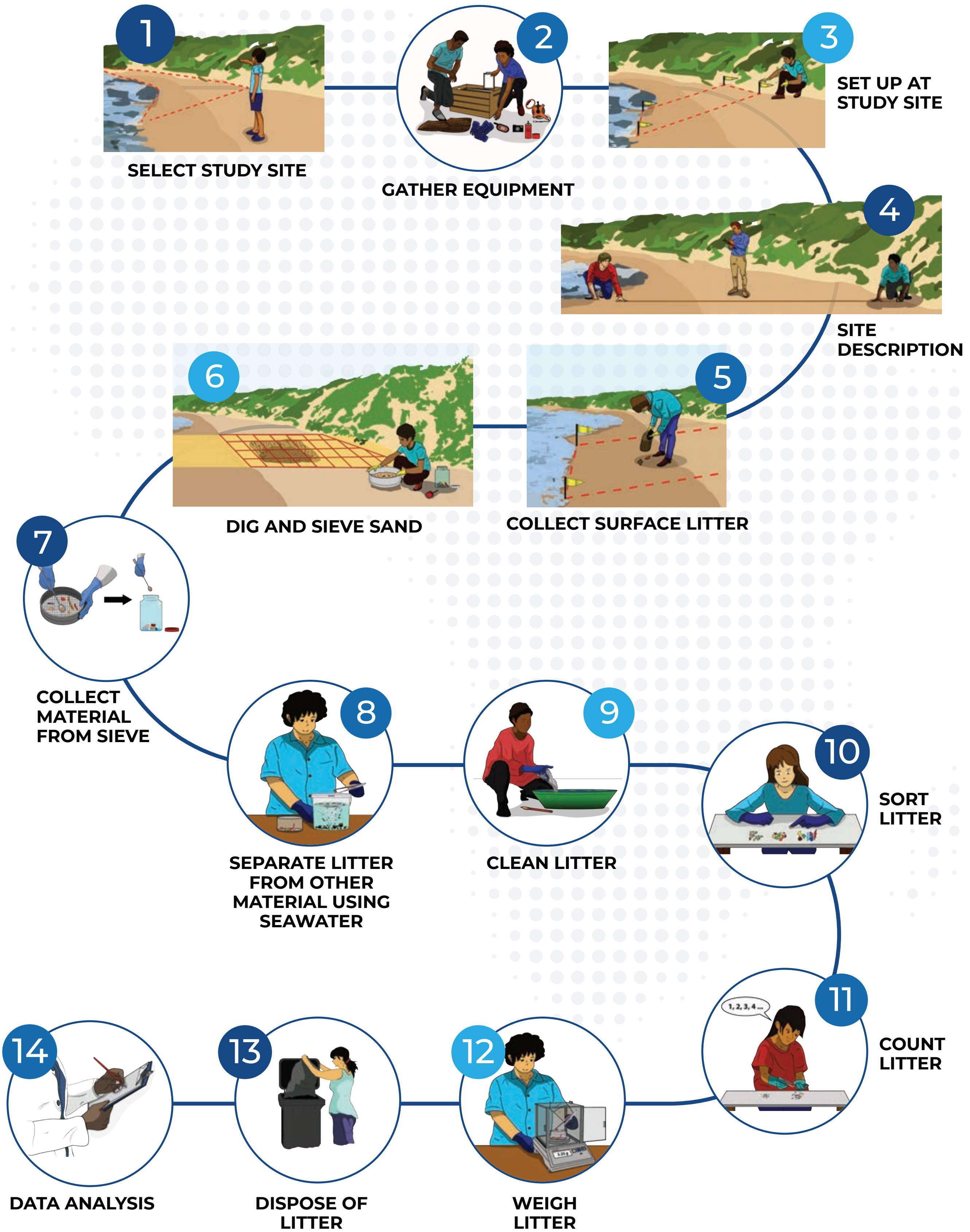
The basic protocol for meso-litter sampling involves collecting litter on the surface of the sand in a strip transect extending from the edge of the water to the storm strandline. Sand is then sieved to a depth of 5 cm from above the most recent strandline to above the storm strandline. Litter between 2 and 25 mm are collected (including plastic pellets or nurdles) to be cleaned, categorized into predetermined litter types (as per the datasheets), and then counted and weighed. At the end of the survey, surveyors will be able to calculate the number and weight of meso-litter per metre of beach. The protocol is detailed below. See **Appendix 5** for a brief field guide for meso-litter surveys.

Note that certain aspects of the sampling protocol are flexible and may be adapted to answer specific research questions and to ensure that the surveys are feasible even when resources are limited. For that and to ensure comparability of results on a large scale, guidelines are presented for adapting protocols by providing three basic approaches to meso-litter surveys (see **Table 4.1**). The recommended minimum requirements for an informative meso-litter survey are provided in the Bronze Standard approach, while the recommended method is highlighted in the Gold Standard approach.

Table 4.1: Suggested approaches for meso-litter surveys on shorelines given the available resources at the surveyors' disposal and level of pollution at the study site

	Gold Standard	Silver Standard	Bronze Standard
Transect length	From the most recent strandline to the storm strandline	From the most recent strandline to the storm strandline	From the most recent strandline to the storm strandline
Transect width	50 cm	50 cm	50 cm
Sieving depth	5 cm	5 cm	5 cm
Transects surveyed	3	1–3	1
Size of litter to survey	2–25 mm	2–25 mm	2–25 mm
Litter counts	Yes	Yes	Yes
Litter weights	Yes	Yes	Optional
Weighing individual pieces of litter	Yes	No. Weight is determined per litter type (e.g., lollipop sticks)	No. Weight is determined per litter type (e.g., lollipop sticks)

Protocol for meso-litter monitoring along shorelines



4.4.1. Set up at the study site

To incorporate different strandlines, meso-litter sampling should be conducted along a 50 cm-wide strip transect from the edge of the water (at low tide), to above the storm strandline (found towards the back of the beach; **Figure 4.1**). The back of the beach is usually easily identifiable by the presence of cliffs, dunes, vegetation, or permanent anthropogenic structures such as roads, buildings, fences and seawalls. In some instances, the back of the beach may be identified by a change in dominant substrate type or topography (e.g., a substantial change in slope). Where possible, transects should be set up in sand bays/slumps along the beach (**Figure 4.2**), because these sites act as accumulation zones for meso-litter.

Two or more transects per study site are recommended in surveys to have replicates and increase the reliability of data. Replicate transects can be 10–50 m apart, depending on the beach topography. Where beaches are very wide and the distance between the most recent strandline and the storm strandline is large, surveying of replicate transects may become challenging. In such instances, rather survey one complete transect (extending from the edge of the water, to above the storm strandline), instead of doing replicates of a transect that do not go all the way to the storm strandline.

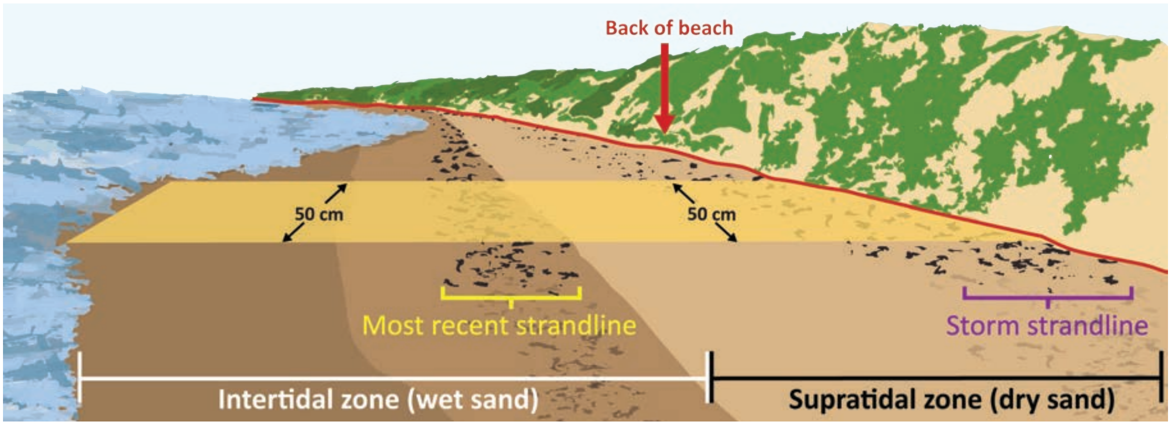


Figure 4.1: Meso-litter sampling should be done along a 50 cm-wide strip transect (shaded yellow above) from the edge of the water to the storm strandline at the back of the beach.

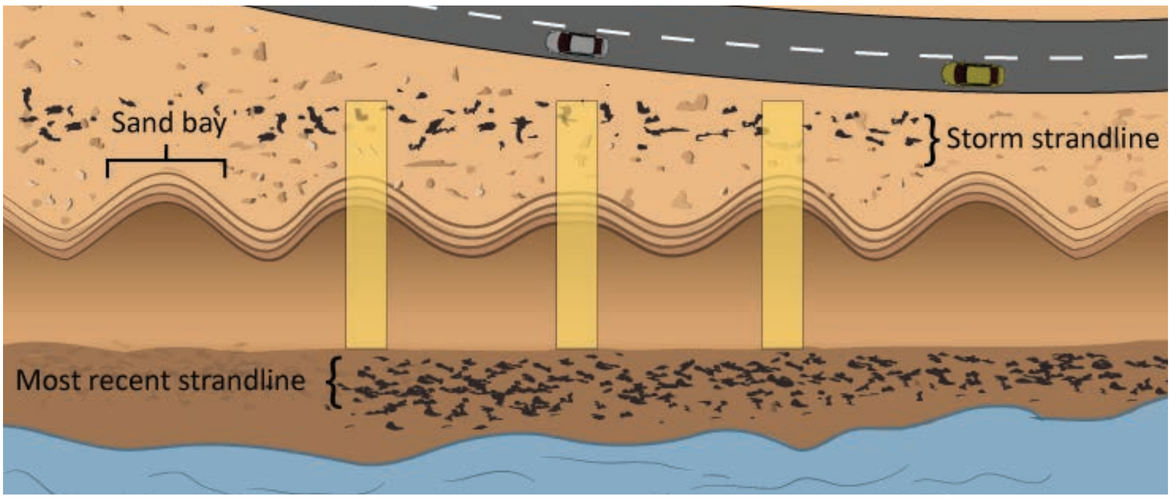


Figure 4.2: Where possible, transects (shaded yellow) should be set up in sand bays/slumps along the beach, because these sites act as accumulation zones for meso-litter.

4.4.2. Site description

Once an appropriate study area has been selected and transect demarcated, study site information should be collected and recorded (**Figure 4.3**) on **Datasheet 1**. This information includes the GPS coordinates, transect length, substrate type, tidal range, nearest town, etc. The site description datasheet needs to be completed once per survey. Information regarding some aspects of the site descriptions is provided below. When reporting results, ensure that the length of the entire transect is specified (the edge of the water to above the storm strandline), as well as the distance from above the most recent strandline to above the storm strandline.

Figure 4.3: Record the study site information on Datasheets 1.

Calculating beach slope

Beach slope can be calculated using the horizontal tidal distance and the vertical tidal range.
Percent (%) slope is calculated as follows:

$$\textit{Slope}\ (\%) = \frac{\textit{Vertical tidal range}}{\textit{Horizontal tidal distance}}\ X100$$

The *horizontal tidal distance* is defined here as the distance from the low-tide to the high-tide water mark (measured when doing the site description). It is not necessary to measure horizontal tidal distance at spring tide, since this will require revisiting sites outside of sampling sessions, and only a crude estimate of slope is required. The *vertical tidal range* is the vertical distance between the spring high-tide and spring low-tide water mark. Vertical tidal range can be obtained from local tidal charts.

4.4.3. Sample collection

1. During low tide, inspect the strip transect from the edge of the water to above the storm strandline and collect all visible litter at the surface of the sand (**Figure 4.4**).

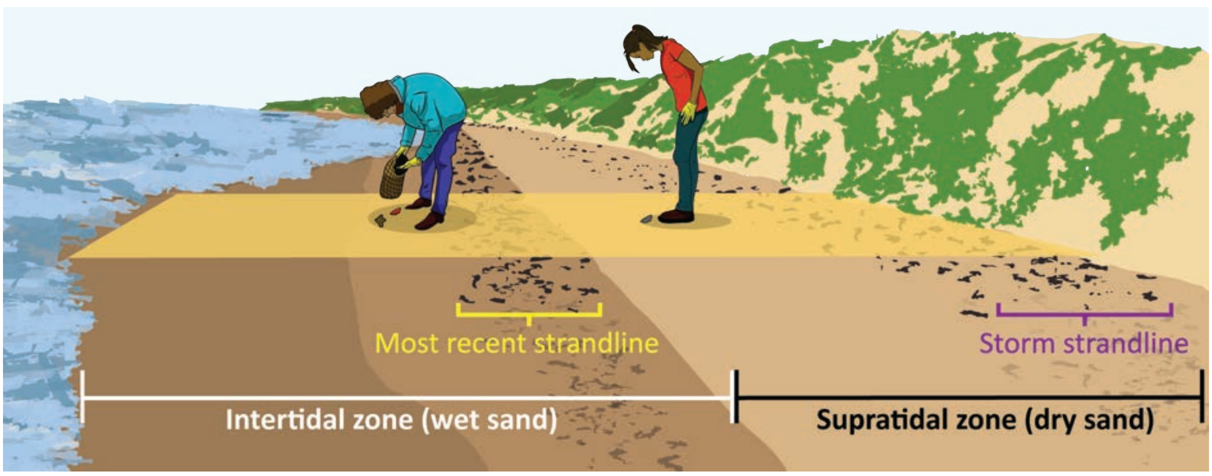


Figure 4.4: Inspect the strip transect (shaded yellow above) from the edge of the water to above the storm strandline and collect all visible litter (2–25 mm) at the surface of the sand.

2. Using a hand spade, collect the upper layer of sand (5 cm deep) inside the strip transect, from the most recent strandline (found at the most recent high-water mark) to above the storm strandline (where the tide no longer has any influence; **Figure 4.5**). A ruler or measuring tape can be used to ensure that the top 5 cm of sand is being collected. This sand will be sieved in Step 3 to collect buried litter.

Surveyors will know when they have reached the end of the storm strandline, because there will no longer be any buried strandlines to sieve through (i.e., the amount of buried seaweed and litter will be substantially lower compared to the rest of the transect). Buried litter is not inspected in the intertidal zone, because waterlogged sand is difficult to sieve.

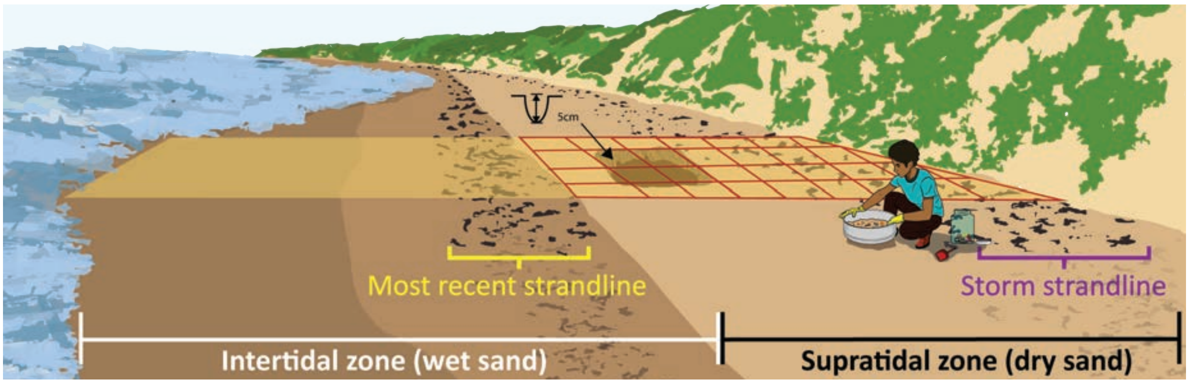


Figure 4.5: Within the strip transect (shaded yellow), collect the upper layer of sand (5 cm deep) from above the most recent strandline to above the storm strandline (red grid) for sieving. Sand below the most recent strandline will not be sieved.

3. The collected sand should be sieved through stacked sieves with mesh sizes of 25 mm and 2 mm (**Figure 4.6**). Litter items on top of the 25 mm sieve and those <2 mm, which will fall through the bottom sieve, should be responsibly discarded during or after the sieving procedure. Special care should be taken to collect litter items between 2 and 25 mm that may fall through the sieves, e.g., long, thin fibres. Only litter/material on top of the 2 mm sieve will be collected for analysis in the laboratory.

4. Easily identifiable pieces of rocks and biological material (e.g. seaweed, shells and twigs) can be removed from the sieves by hand or with forceps. The remaining litter on top of the 2 mm sieve is then transferred to containers or bags (**Figure 4.7**) for processing in the laboratory. It is recommended to process the litter in a laboratory or at an appropriate closed location, since small and light litter items (e.g., polystyrene and film pieces) may be easily lost in the field. Collection bags/containers should be clearly labelled to include the study site name, and date of collection.

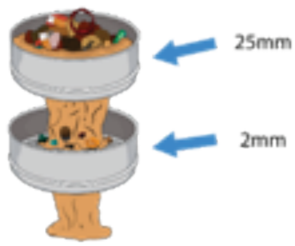


Figure 4.6: Sand should be sieved through stacked sieves with 25 mm and 2 mm mesh sizes.

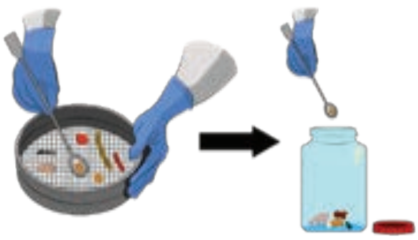


Figure 4.7: Transfer contents of the sieves to containers for processing in the laboratory.

> Optional: Buried litter >25 mm obtained during the meso-litter sampling can be collected and recorded separately to give additional information about buried macro-litter loads.

4.4.4. Laboratory analysis/ litter processing

1. Once in the laboratory, easily identifiable pieces of litter can be collected by hand or with forceps for further analysis. To minimize the risk of overlooking small plastic items, all remaining debris should be added to a 20 L bucket of seawater. Most plastic fragments that wash up on beaches are less dense than seawater and float, making it easier to collect them.

Solid plastic particles made from polymers with a greater density than seawater do not float but can be detected by vigorously stirring the water in the bucket, causing high-density plastics to swirl around in the seawater for longer than fragments of shell or stone (**Figure 4.8**). These floating fragments of litter can be collected by hand or with forceps. Alternatively, a small net with a 2 mm mesh can be used to catch floating plastics in the swirling water. The remaining materials (e.g., sand, shells and seaweed) which do not qualify as litter should be discarded in an appropriate manner.

Figure 4.8: Meso-litter particles floating in a bucket of swirled seawater. The floating meso-litter particles can easily be collected, while items such as seashells sink to the bottom of the bucket faster than the plastic particles.

2. Litter should be sorted into appropriate fragment size categories as per **Datasheet 5** (i.e., 2–5 mm, 5–10 mm, and 10–25 mm). In this manual, litter items are sorted into size categories based on their longest dimension. Sieving is therefore not advised on its own to separate litter items into specific size categories, since it sorts items by their smallest dimension. It is therefore recommended to perform sieving (using sieves with mesh sizes of 2 mm, 5 mm, 10 mm) as an initial step to sort fragments rapidly, but to then confirm the sorting by manually measuring fragments by hand using diagrams such as the one shown here (**Figure 4.9**). Alternatively, grids of different sizes may be used to sort items according to fragment size (**Appendix 6**). This sorting of items may also be completed after all items have been washed (see Step 3a).

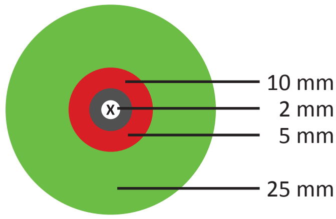


Figure 4.9: Diagram of circles with varying diameters (to scale) that can be used to sort meso-litter items into size categories.

3. After litter pieces have been separated from other materials, all litter pieces must be:

a. Cleaned with water or brushes to remove any remaining sand and/or biological material that may influence weight measurements.
b. Air-dried, to ensure that all items are dry before weighing. Note that some pieces of litter such as fabric may require more time to dry than others.
c. Counted and categorized as per the meso-litter datasheet (**Datasheet 5**). See **Appendix 7** for a visual guide of meso-litter categories.
d. Weighed per category (e.g., "Ropes/Fibres") to the nearest 1 mg/ 0.001 g.

Optional: If researchers are interested in weights of meso-litter fragments, pieces of litter can be weighed individually. If pieces in the same category weigh <1 mg (e.g. foam fragments), it is recommended to weigh a cluster of 10 or 20 pieces together and calculate (and record) the average weight for those fragments.

4. Once the survey is completed and all the meso-litter items have been weighed and categorized by size, collected litter must be correctly disposed of or stored for further analysis (**Figure 4.10**).

5. Frequency of sampling will depend on the research question. In South Africa, meso-litter loads have been shown to remain similar over decades[8], indicating that frequent sampling is not necessary to determine baselines. However, some beaches may display temporal changes in meso-litter within a short timeframe. It is therefore recommended to do annual surveys to determine baselines of meso-litter loads and to investigate whether temporal changes in loads occur in the short-term. If surveyors are interested in short-term changes in micro-and meso-litter loads, then swash lines may be sampled[10].

Figure 4.10: Litter should be disposed of correctly after the survey is completed.

4.5. Data analysis

The total number and weight of items will be calculated per metre of beach (e.g., 5 items.m^{-1} and 20.0 mg.m^{-1}). This should be calculated as a total (i.e., all litter), per litter category (e.g., plastic vs. non-plastic objects), per litter type (e.g., cigarette butts), and per fragment size category. This will allow surveyors/researchers to compare broader results (per category and in total) between sites and over time, while also being able to detect changes in the number and weight of litter items over time. The latter is important to inform and monitor the effectiveness of litter reduction methods.

Chapter 5

Macro-litter monitoring in mangroves

©Doorvasha Joydawo

Chandani Appadoo, Linisha Seeruttun & Sushma Mattan-Moorgawa

Chapter 5

5.1. Introduction

Mangroves are important coastal ecosystems that form a belt between land and sea. These habitats provide many ecosystem services and are characterized by a diversity of mangrove plants. In the Western Indian Ocean (WIO) region, there are 9 species of mangroves[1].
The mangrove ecosystem environment usually has muddy sediment with tall vegetation and seedlings. Mangroves generally have prop roots (for support) and pneumatophores (respiratory roots that grow upwards), which can act as marine litter traps (**Figure 5.1**). The extensive root systems of mangroves form a filter, which may cause entanglement of marine litter whether it be directly disposed of, abandoned, or transported by water or wind. The litter obstructs tidal channels of mangroves and impacts on near shore marine habitats and their biota[2].

Figure 5.1: Marine litter entangled on mangrove prop roots.

Marine litter accumulation can result in several problems, including habitat suppression and direct mortality of animal species, as well as direct/indirect costs associated with a weakened local economy due to loss of tourism activities and reduction of local livelihoods dependent on these ecosystems[3]. Some of the consequences of the presence of litter in the mangrove ecosystem can be ingestion by organisms, entanglement in trapped litter and complete obstruction of crab holes[4]. Crab bioturbation processes, which aid in the provision of plant nutrients and thereby improve mangrove variability, are inhibited by trapped anthropogenic marine litter, leading to unfavourable soil conditions[5]. This may result in a decline in mangrove primary production and an increased mangrove mortality, ultimately affecting functionality of the mangrove ecosystem[5]. Marine litter load can also degrade water quality in the surrounding environment and lead to smothered mangrove seedlings[6].

It is therefore crucial to monitor litter in mangroves to assess the severity of the macro-litter problem in this environment, to understand its extent and impact in mangroves over time, to identify its potential sources and to help adopt preventive measures and effective management strategies. At present, despite the ecological and economic value of mangroves, few studies focus on marine litter in mangroves worldwide, and virtually none exists from the WIO region. This chapter outlines protocols for the monitoring of marine litter in mangroves within the WIO region. It should be noted that the suitability of these protocols will depend on the mangrove characteristics (e.g., plant species composition, tree density, tidal influence, inundation zones, etc.) and protocols may need to be adapted to specific local conditions. Marine litter loads in mangroves can be studied using standing-stock or accumulation surveys (see **Chapter 3**).

5.2. Site selection criteria

1. Description of study site – Macro-litter surveys in mangrove sites are conducted along a predetermined length of shore parallel to the ocean (see accumulation survey protocols below). The study area extends from the edge of the water to the inside of the mangrove belt for a predetermined width.

2. Safety precautions and consideration for natural ecosystems – Surveys should not be conducted at sites where sampling may pose a risk to surveyors, and/or to endangered or protected habitats and species (e.g., nesting turtles). Surveys should not disrupt or harm natural ecosystems. Care should be taken not to cause damage to seedlings or parts of the mangrove plants during surveys.

3. **Access to sites** – Sites should have clear, year-round access for surveyors. The appropriate permits or authorization should be obtained from the relevant authorities where necessary.

4. **Clean-up activities by third parties** – No regular public clean-up activities should take place at the study site. If potential sites are regularly cleaned, surveyors should make the appropriate arrangements with local authorities to ensure that study sites are not cleaned during an accumulation study.

5. **General site conditions requ**ired – The mangrove forest should not be too dense and should allow surveyors to walk through it with relative ease during the survey.

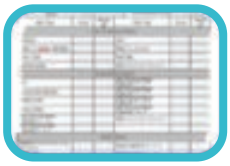
6. **Study site dimensions** - mangrove study sites are 60 m in width and 210 m in length.

7. **Study site selection** – Several sites should be chosen for comparison, in accordance to the specific question to be answered. Random site selection may not be possible, as sites will likely need to vary in proximity to a landfill, urban areas, commercial areas, industrial areas, etc., depending on the research question. In such instances, site selection should be guided by knowledge/expectations of the amount and type of litter that may be found at a site (based on the factors mentioned above), without first visiting the site to investigate litter loads.

*Please contact SST if there is any uncertainty regarding the study site requirements.

5.3. Equipment list


1. Writing equipment and clipboards


2. Datasheets 1-4


3. Demarcation flags/signs


4. Camera


5. GPS device or cellphone


6. Measuring tape (50 m)


7. Work gloves


8. Bags/containers to collect litter


9. Ropes (raffia/other) Size: 8 x 10 m ropes Size: 1 x 70 m rope


10. Poles (PVC/wooden) Size: 4 x 100 cm poles


11. Small hammer


12. Rubber boots


13. Environmentally friendly paint/markers


14. Bucket & clean brush


15. Scales (0.1 g & 1 kg resolution)

5.4. Standing-stock survey

Standing-stock surveys are conducted at a single point in time (i.e., over a single day). The protocol for a standing stock survey is similar to the one used for an accumulation survey (see below). For differences between standing-stock surveys and accumulation surveys, see **Table 5.1**. In mangroves, all field work should be conducted at low tides (LT). Macro-litter (>25 mm) visible on the surface of sediments or entangled between mangrove roots is collected, cleaned, categorized, and weighed. Smaller items such as cigarette butts and caps/lids should also be included, since these are common litter items. Information on site description, site condition, brand audit, and macro-litter datasheets (**Datasheets 1-4**), must be filled in. Since standing-stock surveys are done only once at a site, surveyors are able to sample more sites with fewer expenses. The recommended transect length for standing-stock surveys is 210 m and the width is 60 m.

Table 5.1: Basic differences between standing-stock surveys and accumulation surveys, for mangroves.

	Standing-stock survey	Accumulation survey
Removal of litter	Optional	Mandatory
Number of sampling days	1 day (normally)	3 non-consecutive days (recommended)
Transect length	210 m	210 m
Transect width	30 m	30 m
Type of data that can be collected	• Litter density • Litter weight • Types of litter	• Litter accumulation rate (count & weight) • Types of litter
Advantages	Quick, easy, cheap	More reliable data

5.5. Accumulation survey

5.5.1. Protocol

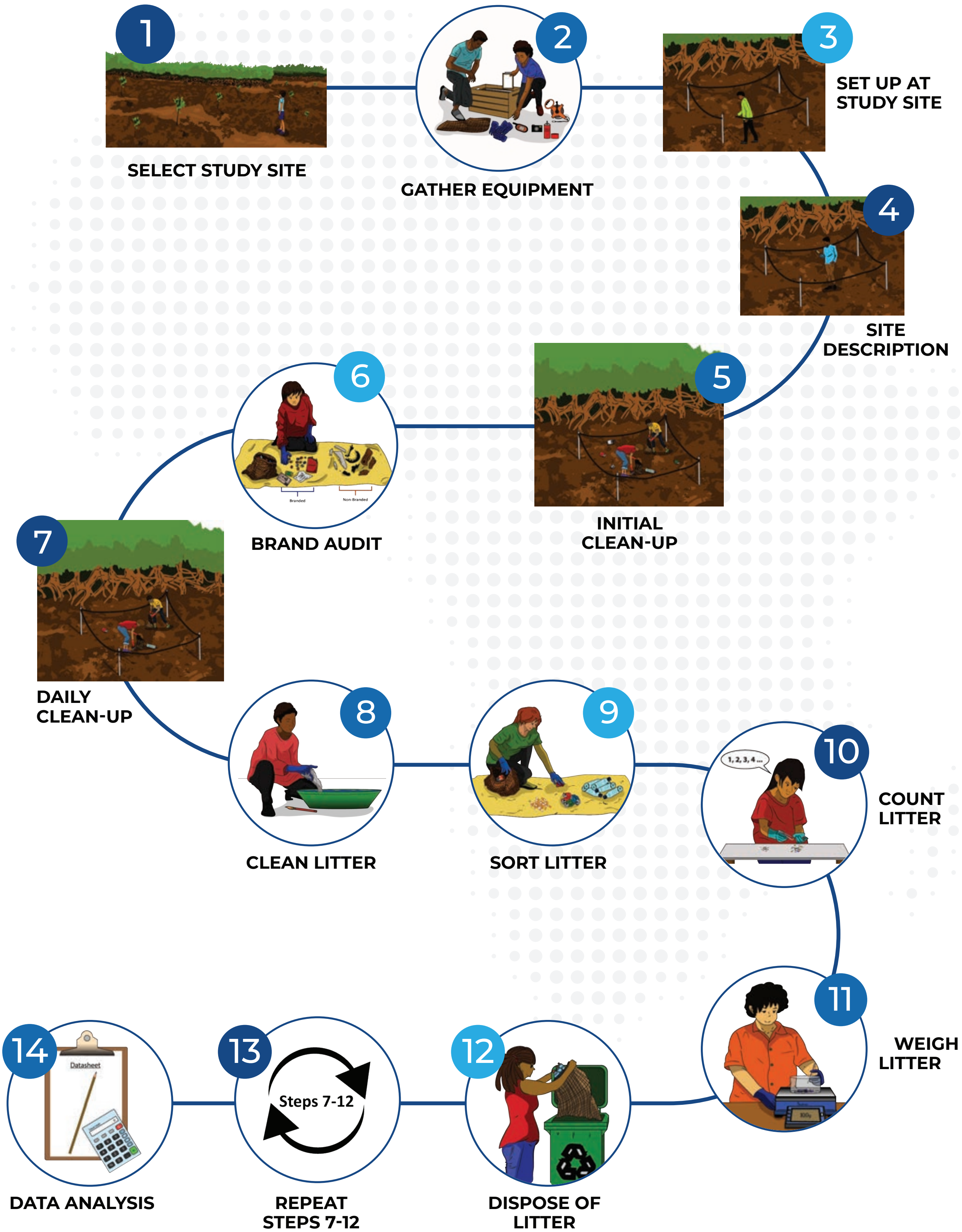
The protocol for an accumulation survey is preceded by an initial Day Zero clean-up of all visible litter on a stretch of 210 m, which represent the standing stock. Thereafter, the same study-site is cleaned on three non-consecutive days, spaced 4 days apart (i.e., after the Day Zero clean-up, surveys will be conducted on Day 1, Day 5 and Day 9. Following each day of the survey, collected litter is cleaned, categorized into pre-determined litter types (as per datasheets), and then counted and weighed. At the end of an accumulation survey, surveyors will be able to calculate the number and weight of litter accumulating per square metre (m^2) per day. See **Appendix 8** for a brief field guide for macro-litter accumulation surveys in mangroves.

Note that certain aspects of the sampling protocol are flexible and may be adapted to answer specific research questions and to ensure that the surveys are feasible when resources are limited. To ensure comparability of results on a large scale, guidelines for adapting protocols are presented by providing three basic approaches to accumulation surveys (see **Table 5.2**). The recommended *minimum* requirements for a reliable accumulation survey are provided in the Bronze Standard approach, while the recommended method is highlighted in the Gold Standard approach. Examples of study-site lengths have been provided here, but surveyors may select any alternative transect length based on the local mangrove characteristics, pollution level, and available resources. By calculating litter loads per square metre of mangrove per day, surveyors can select a custom study-site length, while ensuring that results are still comparable with those of other studies.

Table 5.2: Basic differences between standing-stock surveys and accumulation surveys, for mangroves.

	Gold standard	Silver standard	Bronze standard
Transect length	210 m	140 m	70 m
Transect width	60 m	60 m	60 m
No. of quadrats	45	30	15
Days of sampling (excluding day zero)	3 (Day1, Day5, Day 9)	2 (Day 1, Day 10)	2 (Day 1, Day 10)
Size of litter survey	>25 mm	>25 mm	>25 mm
Day zero initial clean-up	Yes	Yes	Yes
Litter counts	Yes	Yes	Yes
Litter weight	Yes	Yes	Yes
Weighing of individual litter pieces	Yes	Yes	Optional

Protocol for macro-litter monitoring in mangroves



5.5.1.1. Set-up at site

1. Mangroves have three different inundation zones that are influenced by tides to various degrees: landward (LW), middle (M) and seaward (SW) zones. Macro-litter accumulation surveys in mangroves are conducted within squares/quadrats running parallel to the shoreline, within all three of these zones.

2. The sampling design consists of three transect lines of 210 m in length set parallel to the shoreline and spaced 15 m apart (**Figures 5.2 & 5.3**). The transect indicating the seaward zone should be set up first at the low water mark each day of the survey. A record of the GPS positions should be made, as the same coordinates will have to be used for setting transects for accumulation surveys. Each transect should be divided into a set of fifteen 10 x 10 m quadrats with 5 m intervals between each quadrat (**Figure 5.2**). These quadrats represent the area to be surveyed and litter is only collected within these quadrats. The study site width should be 60 m. For 210 m transects, a total of 45 quadrats will be surveyed per site. It is recommended to allocate specific numbers or codes to each quadrat to track which litter was collected in which quadrat (e.g., SWZ 1 for seaward zone 1 or LWZ 4 for landward zone 4).

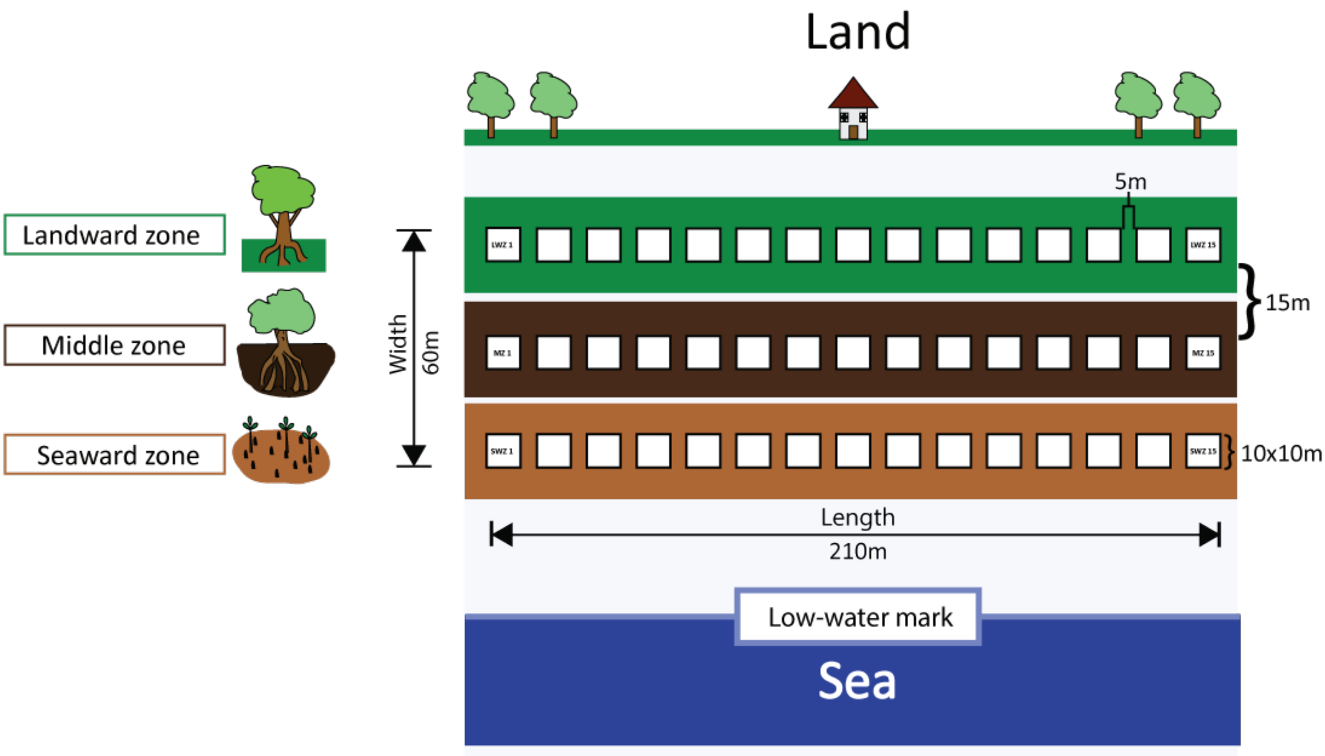


Figure 5.2: Schematic drawing of the sampling design for macro-litter surveys in mangroves. Three transects are set up parallel to the shoreline to demarcate specific zones for sampling. Fifteen 10 x 10 m quadrats are sampled per zone.

3. Each of the 45 quadrats (in a 210 m transect) are set up by hammering four PVC pipes into the ground to form a square with 10 m long sides (**Figure 5.3a**). A border can be formed around each quadrat by tying a 10 m-long raffia rope to each pole and then to the adjacent pole, until the ropes surround the entire quadrat (**Figure 5.3b & c**). A total of four 10 m ropes will be used per quadrat.

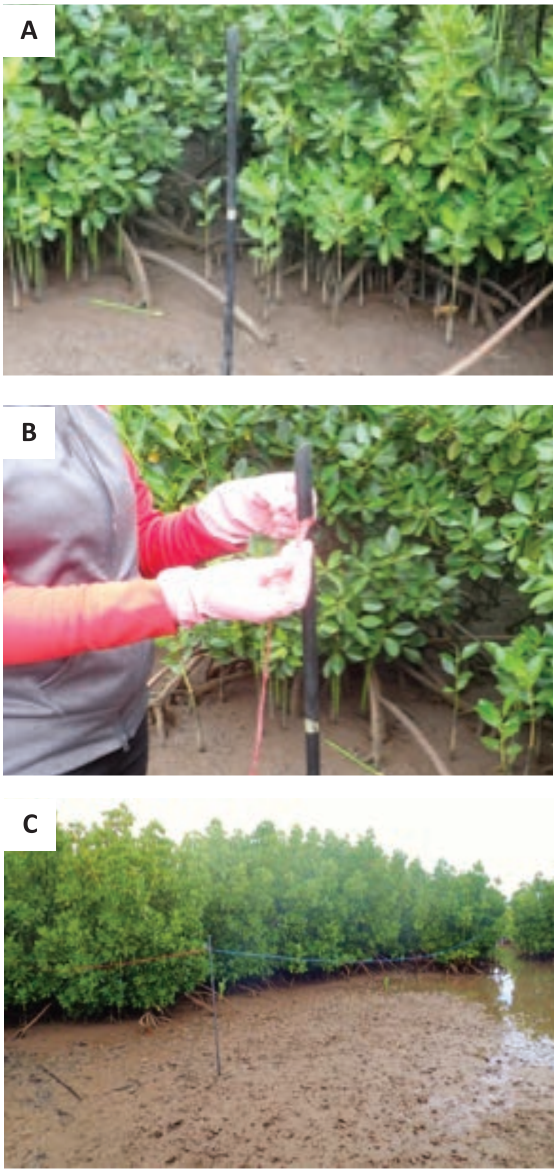


Figure 5.3: PVC pipes are used to mark out quadrats with 10 m-long sides (A). A 10 m raffia rope is tied to each pole (B) and the adjacent pole to form a border around each quadrat (C). Only the area within the quadrats should be surveyed for macro-litter.

4. Quadrats may be subdivided into four 5m x 5m quadrats to facilitate sampling of macro-litter. Surveyors should, however, ensure that the whole 10 x 10 m quadrat is still sampled by the end of each day.

5. A total of 45 quadrats, each measuring 100 m^2 (0.01 ha), should be obtained. The quadrats are set using ropes to allow some flexibility and surveyors may need to bend the ropes to get around trees or dense vegetation.

6. If the study site does not meet the minimum width requirement of 60 m, then it is recommended to survey two transects (one seaward and one middle/landward) instead of three. These transects should be spaced 15 m apart as above, and will reduce the required study site width to 35 m. If study sites are still too narrow, then the spacing between transects can be reduced to between 5 and 15 m. Note that it is crucial to maintain a quadrat size of 10 x 10 m and to keep the spacing between transects constant during and between surveys.

5.5.1.2. Site description

Once an appropriate study site has been selected and demarcated, study site information should be recorded (**Figure 5.4**). Please see **Datasheet 1** for the information required for the study site description (e.g., GPS coordinates for the start and end of the transect, site width, substrate type, etc.). This datasheet should only be completed once per survey (on Day Zero). In contrast, daily changes in site conditions (e.g., weather and wind speeds) need to be recorded on **Datasheet 2** every time the site is surveyed. Information regarding some aspects of the site descriptions is provided below.

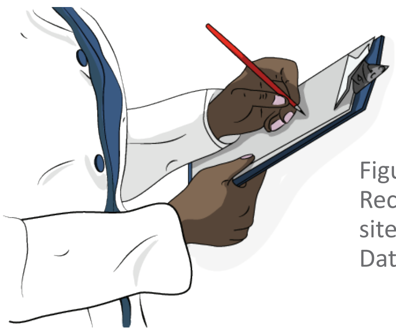


Figure 5.4: Record the study site information in Datasheets 1 & 2.

Calculating slope

Slope can be calculated using the horizontal tidal distance and the vertical tidal range. Percent (%) slope is calculated as follows:

$$Slope\ (\%) = \frac{Vertical\ tidal\ range}{Horizontal\ tidal\ distance} \times 100$$

The *horizontal tidal distance* is defined here as the distance from the low-tide to the high-tide water mark (measured when doing the site description). It is not necessary to measure horizontal tidal distance at spring tide, since this will require revisiting sites outside of sampling sessions, and only a crude estimate of slope is required. The *vertical tidal range* is the vertical distance between the spring high-tide and spring low-tide water mark. Vertical tidal range can be obtained from local tidal charts.

5.5.1.3. Day Zero clean-up/ Standing-stock surveys

Prior to beginning a new accumulation study, all visible litter (>25 mm) on the surface or protruding from the surface should be removed from each quadrat in the study site in an initial clean-up event (defined here as the Day Zero clean-up). Smaller items such as cigarette butts and caps/lids should also be included, since these are common litter items. Litter collected during an initial clean-up of the study area can be used for standing-stock surveys, but should not be incorporated into an accumulation survey. Clean quadrats with zero litter are required before daily litter accumulation can be measured. The litter is then collected separately for each quadrat and placed in well-labelled re-usable refuse bags. Where possible, the immediate vicinity around the study area should be cleaned to ensure that accumulation estimates are not influenced by lateral movement of litter.

Brand audits on the litter collected are recommended on Day Zero (see **Brand Auditing**). If study areas are heavily polluted, brand audits can be performed on a sub-sample of the litter. Please contact SST if there is any uncertainty regarding the sub-sampling for brand audits.

5.5.1.4. Brand auditing

By counting and categorizing branded litter found during clean-ups of polluted sites, information can be obtained regarding the type and origin of litter. Brand audits are recommended for every litter survey. Here we present protocols adapted from the '#BreakFreeFromPlastic' official brand audit protocols. '#BreakFreeFromPlastic' has developed a protocol to conduct plastic brand audits on a global scale. The coalition gathers the results of global brand audits to compile a report highlighting the brands and types of plastics commonly found at clean-ups around the world. To maximize the impact of clean-ups, it is recommended that official brand audits are submitted to the '#BreakFreeFromPlastic' website. It should be noted that there are some key differences between the protocols presented here and that of '#BreakFreeFromPlastic'. The primary goal of brand audits in the context of this manual is to obtain information regarding the source of the litter and the persistence of litter in the environment. The official '#BreakFreeFromPlastic' protocols have thus been modified to include all litter (as opposed to just plastic) and to only include branded items with the relevant information to answer the research questions stated above. Surveyors interested in performing the official '#BreakFreeFromPlastic' plastic brand audit should therefore visit their official website, for more information and to ensure that they collect the appropriate information, at https://www.breakfreefromplastic.org/brandaudittoolkit/.

Brand audits can be performed on litter from standing-stock surveys or on the litter collected on Day Zero of an accumulation survey. To facilitate brand audits, branded and non-branded litter may be separated during clean-ups. After collection, each piece of branded litter should be counted and categorized as per the brand audit datasheet (**Datasheet 3**). Information regarding the brand name, manufacturer, source of the litter (local or foreign), type of product, type of material, type of layers (for plastic items), and date manufactured or best before (BB) dates (when date manufactured is not available) are required for each piece of branded litter (**Figure 5.5**). Where possible, the location of sale can be recorded for receipts or other items. A visual guide (**Appendix 2**) is available to aid in identifying the type of product and packaging for each piece of litter recorded.

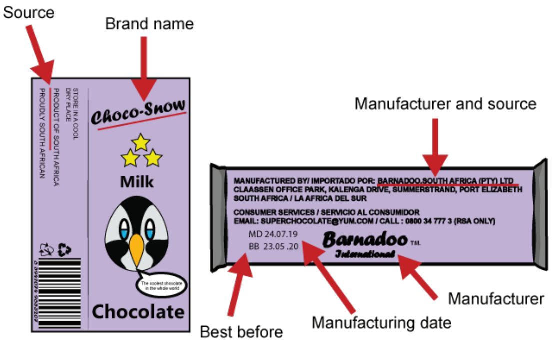


Figure 5.5: Information regarding the brand name, manufacturer, date manufactured, and source of the litter that can be found on branded items.

The *product source* is defined here as the country where the product was most likely discarded (as opposed to just the country of manufacture). Some products may be imported from foreign countries (e.g., China), then bought and thrown away locally. In such instances, especially for litter washing up on seashores, the origin of the litter is uncertain. It is necessary therefore to identify items manufactured elsewhere but sold locally. Brand audits from litter surveys on land are useful to compile a master list of branded items that are known to be sold/found locally. This list could help determine the source of litter washing up on shorelines and reduce the uncertainty and potential bias regarding the source of beach litter.

When the packaging is fragmented or stained and not all required information is visible, available information should be recorded as per the brand audit datasheet and 'N/V' recorded for information not visible. Information regarding the manufacturer and source of the litter can be researched if the brand is known. Only items that include at least one of the following need to be incorporated into the brand audit: 1) brand, 2) manufacturer, 3) source of the litter, 4) date of manufacturing, and/or 5) best before date. Items without this information, therefore, do not need to be included in the brand audit. However, if surveyors are interested in a more comprehensive survey that also includes non-branded items, then information regarding types of products and material can also be included in brand audits, even when the previously mentioned information is not available (as is the case in the official 'BreakFreeFromPlastic' brand audit).

5.5.1.5. Accumulation survey sample collection

1. The 45 quadrats cleaned on Day Zero will be surveyed daily at low tide on Day1, Day 5 and Day 9, starting the day after the Day Zero (Standing-Stock) clean-up, to collect any accumulated litter. Ensure that all quadrats are surveyed thoroughly and cleared of all accumulated litter.

2. Every piece of litter encountered should be collected for analysis in the laboratory (**Figure 5.6**). In the spirit of reducing single-use plastic waste, it is recommended that, wherever possible, surveyors should use reusable bags/containers to collect daily litter.

Figure 5.6: Collect every piece of litter on the surface or protruding from the surface.

Litter collected in different quadrats should be kept separate. Collection bags/containers should be clearly labelled to include the study site name, date of collection, zone of collection (i.e., seaward, middle, or landward zone), and quadrat number.

3. If an item of litter is too large to be removed (e.g., tractor tyres or buried ropes/nets), make a clear, recognizable mark (e.g., using paint) on the item (**Figure 5.7**). This prevents the object from being counted in subsequent surveys.

An alternative is to photograph it and note the locality. Heavy or large items should be recorded, counted and weighed where possible. If items are too heavy to weigh, the mass may be estimated by: 1) measuring the dimensions of the object (using a measuring tape), 2) calculating the volume of the object, and 3) multiplying volume by density of the type of material. The density of materials can be found on the internet. To facilitate mass calculations at a later stage, be sure to record the type of material alongside the type of item in the datasheet (e.g., 'Large Tractor Tyre [Rubber]').

Figure 5.7: To prevent counting the same items twice, make a clear, recognizable mark (e.g., using paint) on items that are too large to be removed from the study site.

4. Potentially dangerous items such as chemicals, weapons, and ammunition should be recorded and counted but not handled (**Figure 5.8**). The relevant authorities should be notified of any potentially dangerous items. It is recommended that the item be photographed, and the locality noted to avoid counting the object in subsequent surveys. The mass of potentially dangerous items should be estimated as previously mentioned in point 3 – estimating the volume of the object and multiplying by the density of the material. For medicines, items may be collected, and the weight estimated, but the contents should not be handled.

5. During an accumulation survey, litter items may be encountered that were not found during the standing stock survey or were exhumed when sediment was displaced during surveys. These items were deposited before the accumulation survey began and should thus be excluded from these surveys. It may prove difficult to determine whether litter has

Figure 5.8: Potentially dangerous items should be recorded and counted but not handled.

been exhumed/missed or newly deposited. Recently exhumed items often look soiled or more degraded than newly washed up material. Surveyors should use their discretion and exclude any items that they suspect have been exhumed/missed during the standing-stock survey.

5.5.1.6 Laboratory analysis/Litter processing

1. Upon returning to the laboratory, or to an appropriate location for analysis of the litter, each piece of litter must be cleaned and dried before weighing. Biological material such as animal and plant material that may influence weight measurements should be removed during the cleaning process (**Figure 5.9**). It is recommended that each piece of litter is rinsed in a bucket of water and air-dried. Where possible, clean brushes (e.g., paintbrushes) can be used to remove soil from dry objects. Brushes may also be used to remove hard-to-reach soil in the folds and corners of the litter. Alternatively, packets and bags may be turned inside-out or torn carefully along the seams (without breaking the litter into more pieces) to remove sediment that accumulates in the corners. Hygiene and sanitation items such as condoms, sanitary pads, tampons and diapers need not be washed or cleaned for weighing. Weights of clean, dry proxies should be used in such cases. The same applies to

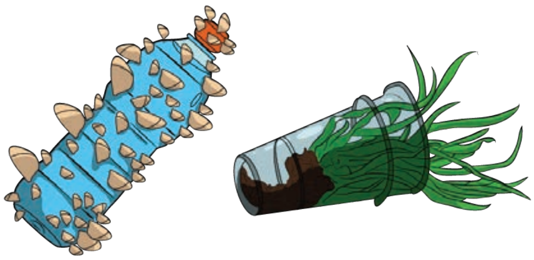


Figure 5.9: Biological material should be removed from litter during the cleaning process.

clothing or other fabric.

2. All pieces of macro-litter must be counted and categorized into litter types as per the litter datasheet (**Datasheet 4**). **Datasheet 4** should be completed daily for each quadrat. See **Appendix 3** for a visual guide to the macro-litter categories and **Box 5.1** for more information about how to process the litter after cleaning it. **Appendix 4** may be used to sort litter fragments into different size classes as required for **Datasheet 4** (**Figure 5.10**).

Figure 5.10: Appendix 4 can be used to sort litter fragments into different size classes as required.

Before weighing the litter, surveyors should ensure that all items are dried properly. Items such as fabric and cigarette butts may take longer to dry. Litter should be weighed per type of litter item to the nearest 0.1 g (**Figure 5.11**). For example, surveyors may have collected 112 lollipop sticks with a total weight of 56.0 g. Some heavier items may require a different scale with a 1 kg resolution. Hooks, sinkers, lures and other fishing equipment should be removed from fishing lines and weighed in their respective litter categories.

Depending on the research question and the available resources, each piece of litter may be weighed individually to provide information

Figure 5.11: Litter should be weighed per type of litter to the nearest 0.1 g.

regarding litter fragment weights. For identical complete items (e.g., earbuds), an average weight per item may be used and multiplied by the number of complete pieces. However, unique and/or fragmented items should be weighed individually when surveyors are concerned with the individual weights of items.

3. Separate datasheets need to be completed for litter collected in each individual quadrat.

4. Once the survey is complete, litter should be disposed of correctly, ideally for recycling, or stored for further analysis (**Figure 5.12**). Biodegradable organic waste can be composted, and recyclable materials can go to recycling and/or material recovery facilities.

Figure 5.12: Litter should be disposed of correctly after the survey is completed.

5. For accumulation surveys, repeat the survey on Day 1, Day 5 and Day 9, within the exact same transects for the initial Day Zero clean-up. Please note that new datasheets for site conditions and litter need to be completed for each day of the survey. The frequency at which surveys are conducted will depend on the research question. If the focus is on establishing litter baselines and monitoring changes over time, then quarterly surveys are recommended. If small changes in litter loads are of concern, then more frequent surveys will be necessary.

Box 5.1. Guidelines for categorization of macro-litter

1. How to categorize fragments of litter:

If fragments are recognizable as being part of a larger item, then it should be recorded as that item. For example, if a fragment of a beverage bottle (see image) can clearly be identified as such, then it should be counted and weighed as a beverage bottle. However, if there is doubt regarding the origin of the fragment, it should be categorized as a fragment according to its properties e.g., 'Plastic fragment – hard (2.5 – 5 cm)' or 'Metal fragment (10 – 25 cm)'.

2. How to count multiple fragments originating from a single item:

If multiple fragments have been collected that can be matched to the same origin (e.g., a single torn sweet packet), it should be recorded as separate fragments, as it would have dispersed separately if not collected. Additionally, it may be hard to keep track of litter fragments when working with large quantities of litter. However, if litter items are torn or broken during or after collection, they should be recorded as one item.

3. How to record entangled items:

If multiple items of litter are entangled, they should be untangled wherever possible and recorded separately (unless otherwise indicated).

4. How to record items consisting of multiple litter types:

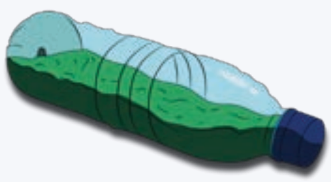
Where litter items from different categories are collected as part of one entity, it should be recorded as the dominant litter type by weight. For example, if a plastic beverage bottle with a bottle cap and drink label is collected, it should be recorded as 'Bottle – Beverage' under the 'Plastic Objects' category. Similarly, a wooden beam with nails embedded will be recorded as a wooden beam.

5. How to categorize an item that is not listed in the datasheet:

If an item is encountered that does not fit into a listed litter type or category, take a photograph, and describe and record it in the 'Others' section as 'Item Name (Material Type)' – for example: 'Matchbox (Cardboard)'.

6. How to weigh items that contain liquids:

If an item contains liquids, the contents should be poured out before weighing. However, if there are safety concerns regarding disposal of the liquid, then an empty proxy of the same type of container can be weighed.



5.6. Data analysis

5.6.1. Estimations based on totals

1. To calculate total marine litter density by counts per inundation zone, add the number of items collected in all of the quadrats within a given inundation zone together and divide this total number of items by the overall area sampled within the inundation zone (items.m^{-2}).

2. Example 1: Figure 5.13 provides an example of litter counts obtained from 15 quadrats (each sized 10 x 10 m) within a single inundation zone. Based on these results, the litter density by counts in the inundation zone in question would be 3000 items (the total count of all items in the quadrats) ÷ 1500 m^2 (the total area sampled in the inundation zone) = 2 items. m^{-2}.

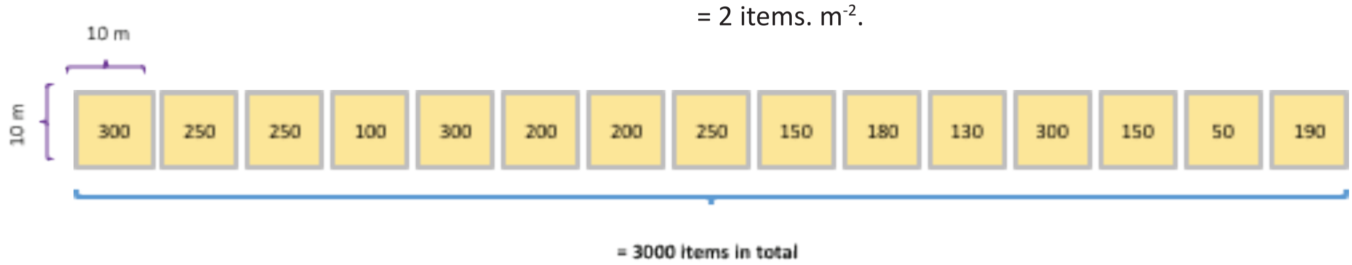


Figure 5.13: Example of litter counts obtained from 15 quadrats (each sized 10 x 10 m) within a single inundation zone.

3. To calculate the total marine litter density by weight, add the weights of the items collected in all of the quadrats within a given inundation zone together and divide this total weight (g) of the items by the overall area sampled (g/m^{-2}).

4. Example 2: Figure 5.14 provides an example of litter weights obtained from 15 quadrats (each sized 10 x 10 m) within a single inundation zone. Based on these results, the litter density by weight in the inundation zone in question would be 600 g (the total weight of all items in the quadrats) ÷ 1500 m^2 (the total area sampled in the inundation zone) = 0.4 g. m^{-2}.

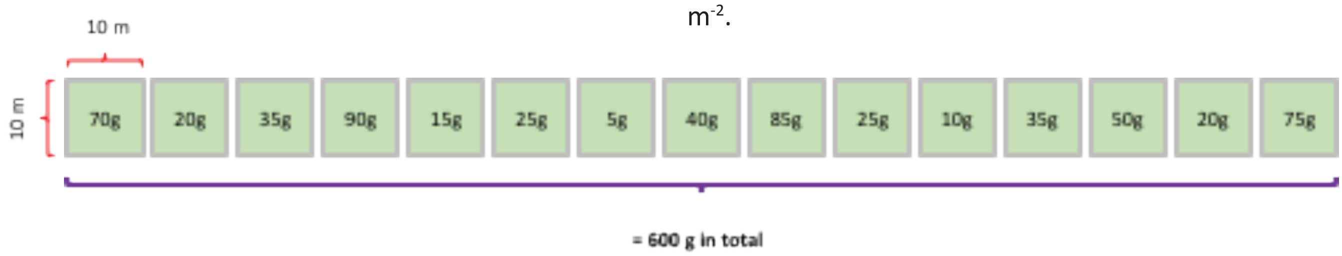


Figure 5.15: Example of litter weights obtained from 15 quadrats (each sized 10 x 10 m) within a single inundation zone.

5.6.2. Estimations based on means

1. Surveyors can obtain useful information regarding the variation in litter loads within inundation zones by calculating the mean density of litter. To determine mean density of different marine litter categories both in terms of count (number of items.m^{-2}) and weight (g.m^{-2}) in each zone, divide the amount of litter (count or weight) in each quadrat by the total area of that quadrat (100 m^2). Add the density results from each quadrat within the same zone together and divide by the number of quadrats.

2. Example 3: Given the counts mentioned in Example 1 for 15 quadrats (each sized 10 x 10

m) within a single inundation zone, the litter count density is provided in **Figure 5.15**. Based on these results, the mean litter density by weight in the inundation zone in question would be 30 (the total density per m^{-2}) ÷ 15 (the total number of quadrats) = 2 $items.m^{-2}$.

Note that this mean density estimate is the same as the density estimate in **Example 1**. The key difference is that variation can be calculated within inundation zones (i.e., how does litter density differ between different quadrats in a zone?).

Figure 5.14: Example of litter count densities obtained from 15 quadrats (each sized 10 x 10 m) within a single inundation zone.

5.7. Acknowledgements

We are grateful to our two trainee project assistants, L Seeruttun and V Gunness, for field photographs and input in litter assessment protocol design.

Chapter 6

Meso-litter monitoring in mangroves

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Chandani Appadoo, Linisha Seeruttun & Sushma Mattan-Moorgawa

Chapter 6

6.1. Introduction

As important nursery, feeding and breeding grounds, mangroves support a rich biodiversity and high levels of productivity, and supply seafood at capacities to feed people[1]. Mangrove habitats are characterized by sediments of varying composition but dominated by small sediment particles. Various studies have focused on quantifying pollution in marine sediments worldwide[2], but few studies have quantified marine litter in mangrove soils due to a difficulty in sampling[3]. Furthermore, most studies on mangroves sediments focus on micro-litter[2] rather than macro-litter (see **Chapter 5**) and meso-litter. Micro-plastics are smaller particles derived from the breakdown of meso-plastics so one can infer that much of the published research on micro-plastics will also be relevant and applicable to meso-plastics.

Meso-litter monitoring in mangroves relates to the collection and study of marine litter components between 2 and 25 mm retained in sediments. Micro and meso-plastics are emerging as the most common plastic particulates found in the marine environment[4]. Several studies have reported the occurrence of micro-plastics in mangrove sediments[3,5]. A range of mangrove biota, e.g., detritus feeders, molluscs, fishes and seabirds, are vulnerable to the ingestion of these micro-plastics and would be equally vulnerable to meso-plastics.

Due to their small sizes and differing colours, meso-plastics can often be mistaken as food and can have harmful effects on organisms such as internal and external injuries, blockages of the gut tract or chemical stress[6]. Transported over long distances by seawater currents and prevailing winds[7], these small plastics can act as a transport medium for absorbed/adsorbed persistent organic pollutants and heavy metals[8]. Meso-plastics and micro-plastics are made up of additives such as organic chemicals, flame retardants, emollients, plasticisers and antimicrobials, which have adverse effects on the marine biota[9]; through bioaccumulation (accumulating in organisms) and biomagnification (increasing in concentration as one goes up the food web), they can be a risk to human health[3]. It is therefore vital to monitor meso-litter in coastal and marine environments, including highly productive mangrove ecosystems.

Owing to its relatively small size, meso-litter is often buried in sediment and unlike macro-litter, it is not targeted in litter cleanups[7]. The monitoring of meso-plastics requires less complicated procedures, is less time-consuming, easier to identify and to classify as compared to micro-plastics and it can be used to provide an estimate of micro-plastic debris abundance[10,11] in the marine environment. Monitoring of meso-litter can be a valuable indicator in assessing the severity of the litter problem, identifying potential sources, and guiding development of preventive measures for this type of pollution.

6.2. Site selection criteria

Meso-litter surveys in mangroves can be conducted within the same study sites as macro-litter accumulation surveys (**Chapter 5**). Site selection criteria for meso-litter surveys are therefore the same as for macro-litter accumulation surveys:

1. Description of study site – Meso-litter surveys in mangroves are conducted within quadrats along a predetermined length of shore parallel to the edge of the water. The study area extends from the edge of the water to inside of the mangrove belt for a predetermined width.

2. Safety precautions and consideration for natural ecosystems – Surveys should not be conducted at sites where sampling may pose a risk to surveyors, and/or to endangered or protected habitats and species (e.g., nesting turtles). Surveys should not disrupt or harm natural ecosystems. Care should be taken not to cause damage to mangrove seedlings, saplings or adult trees during survey or sampling.

3. Access to sites – Sites should have clear, year-round access for surveyors. The appropriate permits or authorization must be obtained from the relevant authorities where necessary.

4. General site conditions required:

- The mangrove forest should not be too dense and should allow surveyors to walk through it with relative ease during survey and sampling.
- Sampling should be conducted at tides that are low enough to permit researchers to walk safely among the mangroves for the duration of the survey.

5. Study site dimensions – The recommended study site length for mangrove forest belts are 31.5 m in width and 84.5 m in length (Gold standard).

6.3. Equipment list


1. Writing equipment and clipboards


2. Datasheets 1 & 5


3. Demarcation flags/signs


4. Camera


5. GPS device or cellphone


6. Measuring tape (50 m)


7. Work gloves


8. Bags/cotainers to collect litter


9. Stackable test sieves OR 50 x 50 cm framed sieves with mesh sizes of 2 mm & 25 mm


10. Small hand spade


11. Scale (1 mg resolution)


12. 5 Litre glass beaker & stirrer


13. Bucket and clean brush

6.4. Protocol

The basic protocol for meso-litter sampling in mangroves involves collecting sediment samples in squares/quadrats placed within three different inundation zones. Sediment samples are taken to a laboratory to be dried before selecting a 1 kg portion/sub-sample per quadrat for further analysis. Litter between 2 and 25 mm are extracted (including plastic pellets or nurdles) from the sediment by means of density separation and sieving. Litter is then cleaned, categorized into predetermined litter types (as per the datasheets), and then counted and weighed. At the end of the survey, surveyors will be able to calculate the number and weight of meso-litter per kilogram of sediment. The protocol is detailed below. See **Appendix 9** for a brief field guide for meso-litter surveys in mangroves.

Note that certain aspects of the sampling protocol are flexible and may be adapted to answer specific research questions and to ensure that the surveys are feasible even when resources are limited. To ensure comparability of results on a large scale, guidelines are presented for adapting protocols by providing three basic approaches to meso-litter surveys in mangroves (see **Table 6.1**). The recommended minimum requirements for an informative meso-litter survey are provided in the Bronze Standard approach, while the recommended method is highlighted in the Gold Standard approach.

Table 6.1: Suggested approaches for meso-litter surveys in mangrove sites given the available resources at the surveyors' disposal and level of pollution at the study site.

	Gold Standard	Silver Standard	Bronze Standard
Transect length	84.5 m	53 m	21.5 m
Transect width	31.5 m	31.5 m	31.5 m
Quadrant size	50 cm x 50 cm	50 cm x 50 cm	50 cm x 50 cm
Number of quadrats surveyed	27	18	9
Size of litter to survey	2-25 mm	2-25 mm	2-25 mm
Litter counts	Yes	Yes	Yes
Litter weights	Yes	Yes	Optional
Weighing individual pieces of litter	Yes	No	No

6.4.1. Set up at the study site

1. Mangroves have three different inundation zones that are influenced by tides to various degrees: landward (LW), middle (M) and seaward (SW) zones. Meso-litter surveys in mangroves are conducted within various squares (10 m x 10 m) running parallel to the shoreline within all three of these zones.

2. The sampling design consists of three transect lines 84.5 m in length, set parallel to the shoreline and spaced 15 m apart (**Figure 6.1**). The transect indicating the seaward zone should be set up first, 5 m above the low-water mark (LWM). Each transect should be divided into nine 50 x 50 cm quadrats with 10 m intervals between each quadrat. These quadrats represent the area to be surveyed, and litter is only collected within these quadrats. The study site width should be 31.5 m. A total of 27 quadrats will be surveyed per site. It is recommended that specific numbers or codes are allocated to each quadrat to track what litter was collected in which quadrat (e.g., SWZ 1 or LWZ 4).

3. Quadrats can be demarcated using small flags, or PVC squares of the appropriate size (see **Figure 6.3**)

4. If the study site does not meet the minimum width requirement of 31.5 m, then it is recommended that two transects are surveyed (one seaward and one middle/landward) instead of three. These transects should be spaced 15 m apart as above and will reduce the required study site width to 16 m (as opposed to 31.5 m). If study sites are narrower than 16 m, then the spacing between transects can be reduced to between 5 and 15 m. Note that it is crucial to maintain a quadrat size of 50 x 50 cm and to keep the spacing between transects constant between surveys.

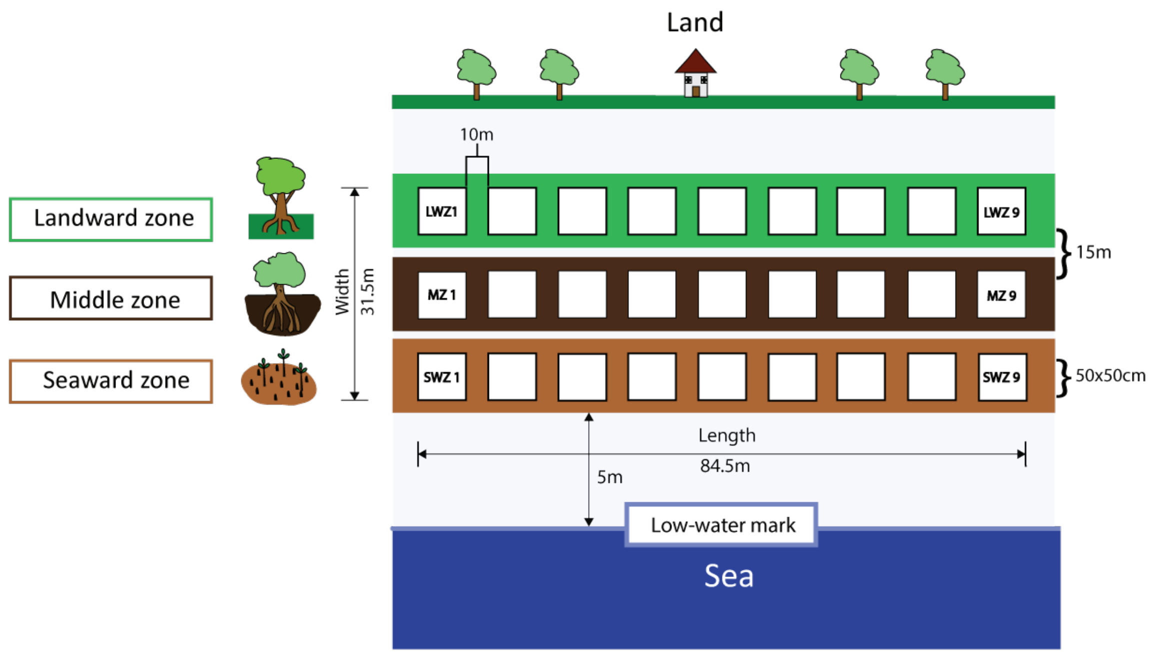


Figure 6.1: Schematic drawing of quadrat (50 x 50 cm) set-up for meso-litter sampling.

6.4.2. Site description

Once an appropriate study area has been selected and the transect demarcated, then study site information should be collected and recorded (**Figure 6.2**) in **Datasheet 1**. This information includes the GPS coordinates, transect length, substrate type, tidal range, nearest town, etc. The site description datasheet only needs to be completed once per survey. Information regarding some aspects of the site descriptions is provided below.

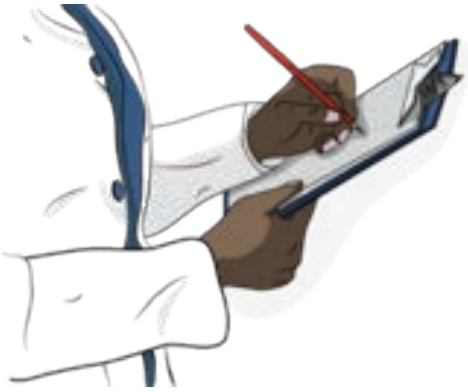


Figure 6.2: Record the study site information in Datasheet 1.

Calculating slope

Slope can be calculated using the horizontal tidal distance and the vertical tidal range. Percent (%) slope is calculated as follows:

$$\text{Slope (\%)} = \frac{\textit{Vertical tidal range}}{\textit{Horizontal tidal distance}} \text{ X100}$$

The *horizontal tidal distance* is defined here as the distance from the low-tide to the high-tide water mark (measured when doing the site description). It is not necessary to measure horizontal tidal distance at spring tide, since this will require revisiting sites outside of sampling sessions, and only a crude estimate of slope is required. The *vertical tidal range* is the vertical distance between the spring high-tide and spring low-tide water mark. Vertical tidal range can be obtained from local tidal charts.

6.4.3. Sample collection

1. Within each quadrat: 1) the top 3 cm of sediment is evenly scraped up using a hand spade; 2) a ruler or measured stick can be used to ensure that the top 3 cm of sediment is being collected; 3) the sediment material is carefully collected in reusable bag or container for subsequent analysis (**Figure 6.3**); 4) Collection bags/containers should be clearly labelled to include the study site name, date of collection, zone of collection (i.e., seaward, middle, or landward zone), and quadrat number.

2. One sediment sample should be collected from each quadrat for quality control.

Figure 6.3. Sample collection for meso-litter using 50 x 50 cm quadrats. A small measured stick is used as a ruler to indicate depth.

6.4.4. Laboratory analysis

6.4.4.1. Select a sub-sample of sediment

Once in the laboratory, each sediment sample from each quadrat should be air-dried. Once dried, a 1 kg sub-sample must be randomly selected from each of the nine sediment samples. These sub-samples should be analysed further for the presence of meso-litter using three steps: density separation, sieving and visual sorting.

6.4.4.2. Density separation

1. A 3 L salt (NaCl) solution with a salt concentration of 1.2 g/cm^3 is prepared by adding 3.6 kg of table salt to 3 L of filtered water in a large glass beaker (**Figure 6.4**). The solution is stirred until all salt particles are dissolved.

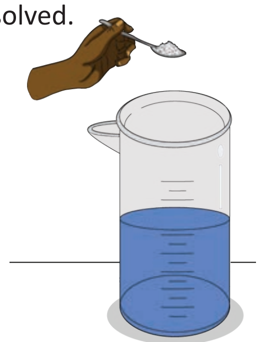


Figure 6.4: Prepare as salt (NaCL) solution by adding salt to filtered water.

2. Add the 1 kg of dry sediment to the glass beaker containing the salt solution and stir vigorously for five minutes with a stirrer (**Figure 6.5a**). The mixture should stand for one hour, during which time the sediment will sink to the bottom and plastic items that are less dense than the salt-water will float to the surface (**Figure 6.5b**). Items denser than the salt-water solution that did not float, will be extracted at a later period (see below).

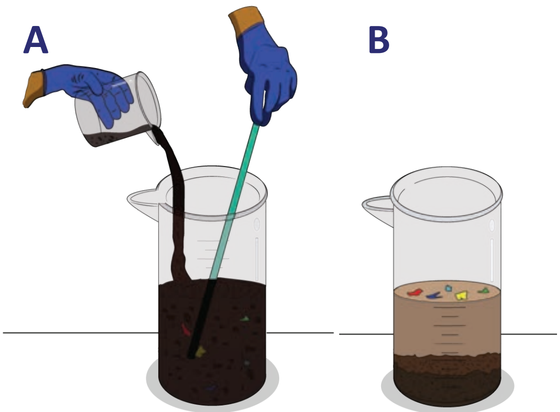


Figure 6.5: Add 1 kg of dry sediment to a glass beaker with a saltwater solution. A) Stir the solution vigorously for five minutes and B) allow the mixture to stand for an hour to allow the sediment to settle at the bottom, while litter items less dense than saltwater will float.

6.4.4.3. Sieving

1. The supernatant (the watery mixture above the sediment) is poured through a cascade of different mesh size metal sieves (sizes of 11 mm, 10 mm, 5 mm, 4 mm, 2 mm) to separate the meso-litter particles by size (**Figure 6.6**).

Figure 6.6: Pour the supernatant through a cascade of sieves with different mesh sizes to sort the litter according to fragment size.

2. Litter should be sorted into appropriate fragment size categories as per **Datasheet 5** (i.e., 2–5 mm, 5–10 mm, and 10–25 mm). In this manual, litter items are sorted into size categories based on their longest dimension. Sieving is therefore not advised on its own to separate litter items into specific size categories, since it sorts items by their smallest dimension. It is therefore recommended to perform sieving (using sieves with mesh sizes of 2 mm, 5 mm, 10 mm) as an initial step to sort fragments rapidly, but to then confirm the sorting by manually measuring fragments by hand using diagrams such as the one shown here (**Figure 6.7**). Alternatively, grids of different sizes may be used to sort items according to fragment size (**Appendix 6**). This sorting of items may also be completed after all items have been washed.

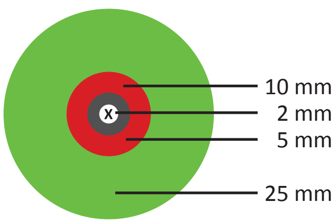


Figure 6.7: Diagram of circles with varying diameters (to scale) that can be used to sort meso-litter items into size categories.

3. Following this initial extraction, density separation and sieving are repeated once using the remaining sediment that settled in the beaker to maximize recovery of meso-litter samples.

4. After removing all floating plastics by means of density separation, the remaining sediment is poured over a clean set of sieves. The sieves are then washed with freshwater to separate any remaining non-floating meso-litter from the sediment. Meso-litter retained on the sieves can be recovered and added to the previously collected litter of the same size for further analysis.

6.4.4.4. Sorting

After litter pieces have been separated from other materials, all litter pieces must be:

1. Cleaned with water or brushes to remove any remaining sand and/or biological material that may influence weight measurements.
2. Air-dried, to ensure that all items are dry before weighing. Note that some pieces of litter such as fabric may require more time to dry than others.
3. Counted and categorized as per the meso-litter datasheet (**Datasheet 5**). See **Appendix 7** for a visual guide of meso-litter categories.
4. Weighed per category (e.g., 'Ropes/Fibres') to the nearest 1 mg/ 0.001 g.

> Optional: If researchers are interested in weights of meso-litter fragments, pieces of litter can be weighed individually. If pieces in the same category weigh <1 mg (e.g. foam fragments), it is recommended to weigh a cluster of 10 or 20 pieces together and calculate (and record) the average weight for those fragments.

6.4.4.5. Dispose of litter

Once the survey is completed and all the meso-litter items have been weighed and categorized by size, collected litter must be correctly disposed of or stored for further analysis (Figure 6.8).

Figure 6.8: Litter should be disposed of correctly after the survey is completed.

6.5. Data analysis

1. To determine the total meso-litter density by count within each inundation zone, first add the number of items collected in all of the quadrats within a given inundation zone together and divide this total number of meso-litter items by the total weight of sediment processed in that zone to determine items.kg^{-1}. **Figure 6.9** provides an example of litter counts obtained by processing 1 kg of sediment in nine different quadrats within an inundation zone. Based on these results, the litter density in that zone would be 72 items ÷ (9 x 1 kg of sediment processed) = 8 items.kg^{-1}.

2. To determine the total meso-litter density by litter weight within each inundation zone, first add the weight of items collected in all of the quadrats within a given inundation zone together and divide this total weight of meso-litter items by the total weight of sediment processed in that zone to determine mg.kg^{-1}. **Figure 6.10** provides an example of litter weights obtained by processing 1 kg of sediment in nine different quadrats within an inundation zone. Based on these results, the litter density by weight in that zone would be 153 mg ÷ (9 x 1 kg of sediment processed) = 17.0 mg.kg^{-1}.

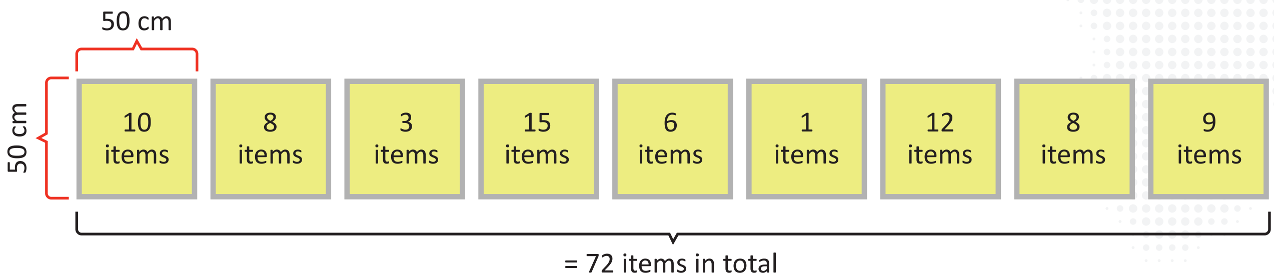


Figure 6.9: Example of litter counts obtained by processing 1 kg of sediment from nine different quadrats in an inundation zone.

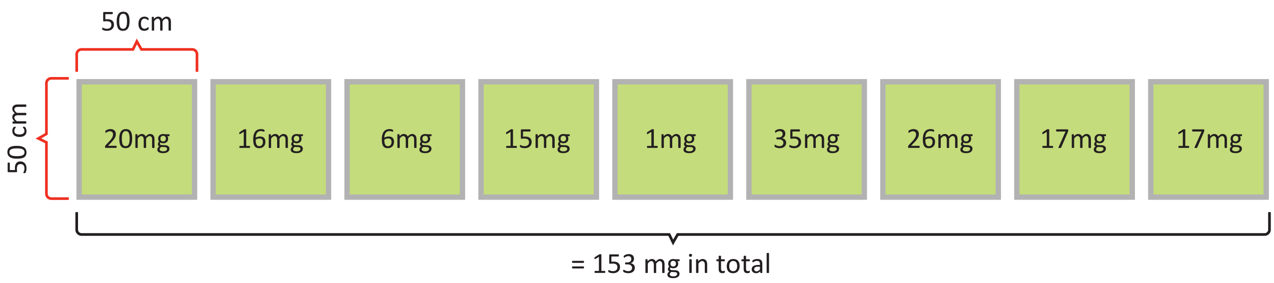
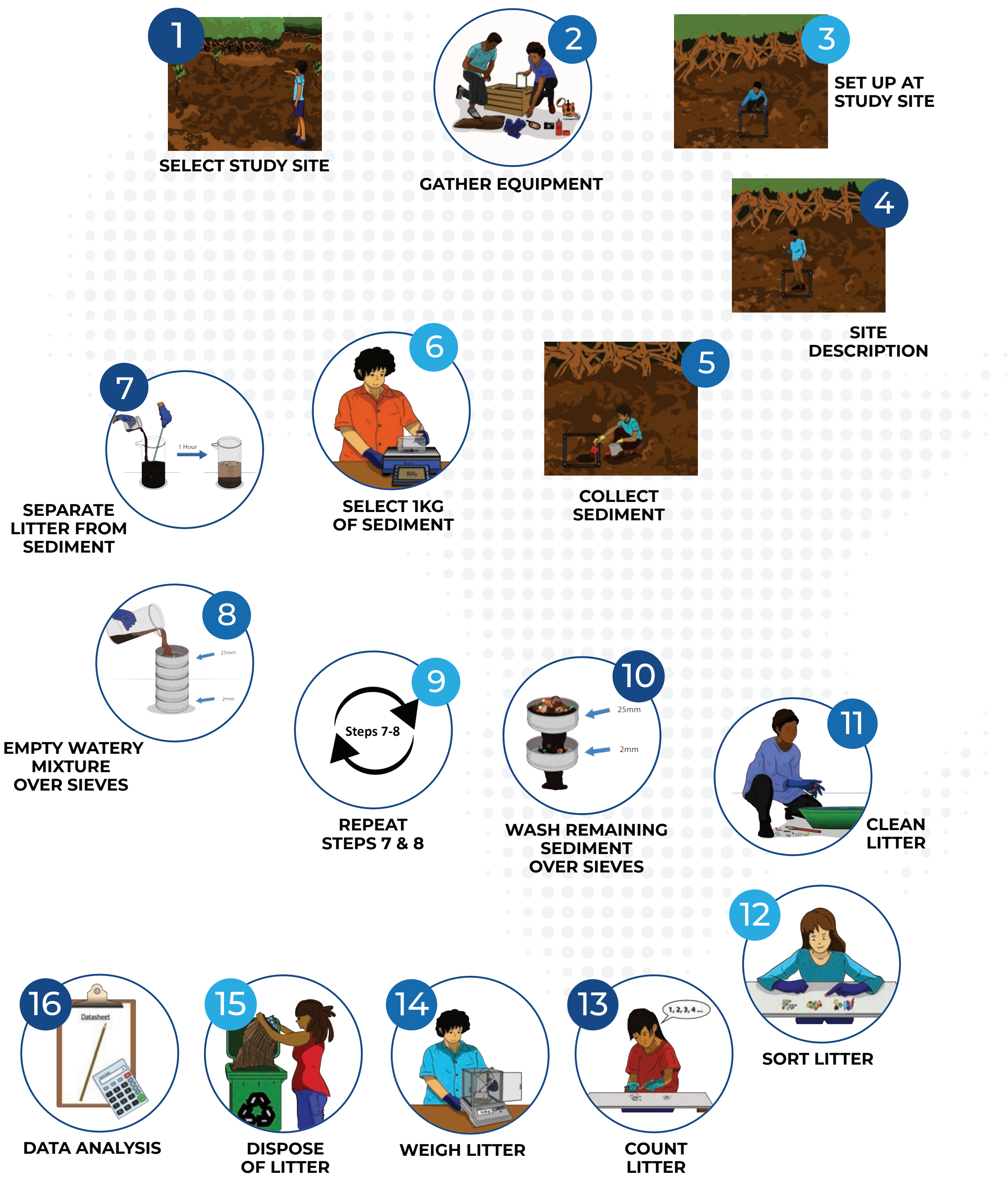


Figure 6.10: Example of litter weights obtained by processing 1 kg of sediment from nine different quadrats in an inundation zone.

3. Litter density should be calculated as a total (i.e., all litter), per litter category (e.g., plastic vs. non-plastic objects), per litter type (e.g., cigarette butts) and per fragment size category.

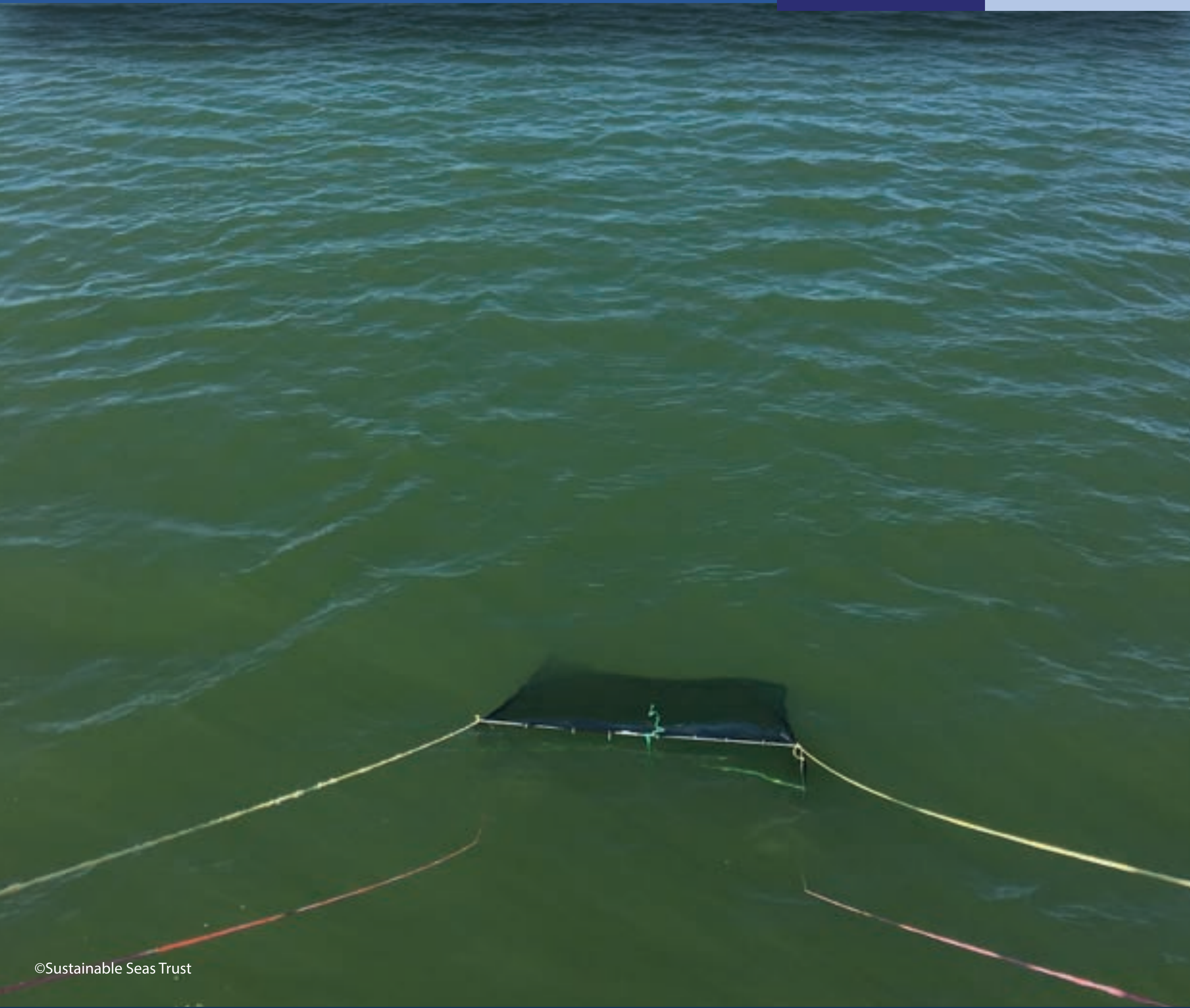
4. Surveyors can obtain useful information regarding the variation in meso-litter loads within inundation zones by calculating the mean density of meso-litter. To determine mean density of different marine litter categories both in terms of count (number of items/kg) and weight (mg/kg) in each zone, divide the amount of litter (count or weight) in each quadrat by the area of that quadrat (2500 cm^2 or 0.25 m^2). Calculating the meso-litter density per quadrat will give an indication of variation in the different quadrats within the same inundation zone. Add the density results from each quadrat within the same zone together and divide by the number of quadrats to get an idea of density variation in each zone.

Protocol for meso-litter monitoring in mangroves



Chapter 7

Litter monitoring in rivers and estuaries



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Toshka Barnardo, Lorien Pichegru & Tatjana Baleta

Chapter 7

7.1. Introduction

Litter from land-based sources is predicted to make up the bulk of marine litter[1]. A large portion of litter from land is washed or blown down catchments into rivers. It also enters waterways from stormwater runoff (often carrying street litter from urban, industrial, and residential areas), run-off from landfills, run-off from agricultural, forestry and mining operations, illegal dumping, inland shipping, and discharge from waste-water treatments[2]. Rivers are therefore the primary form of transport of litter from land to the ocean, sometimes carrying litter great distances from inland to the coast[1,3,4]. It is estimated that between 0.5 and 12.7 million tonnes of plastic enter the ocean via rivers every year[1,3,4]. This wide range of estimates illustrates the need for more local studies of litter loads in rivers to provide data to strengthen global models of litter entering the ocean.

Litter transported down rivers increases litter loads in the ocean[1,3,4] and on beaches[5,6], where it has harmful ecological, social, and economic repercussions[7,8,9]. Few studies have quantified the impact of riverine litter on river ecosystems, but the impact is likely similar to that of litter in marine environments[10]. This includes ingestion and entanglement by wildlife, leakage of toxins into the environment, and affecting human livelihoods negatively[10].
The characteristics of the catchment area and the human activities within it (including population density and economic activity), affect the amounts and types of litter flowing down rivers. Physical and natural characteristics include catchment size, topography, climate, types of riverbanks, and river size, flow, and shape[3,11,12]. Anthropogenic influences such as type of land-use (e.g., industrial, commercial, residential, or rural developments), population density, the presence of dams/weirs, accessibility of the river, and littering behaviour also influence litter in rivers[5,11,13]. It is therefore important to assess these underlying factors to develop effective litter management strategies in river catchments. Remote sensing and Geographic Information System (GIS) technology are valuable tools to map the catchment area and evaluate how natural and anthropogenic influences contribute to litter loads measured in the river.

Litter can be found and subsequently studied in various parts of a river[2]. These include the water column, the riverbed, riverbanks, and vegetation within the river. Many studies have focused on assessing floating litter loads in rivers, using a wide range of techniques[11,12,14,15]. Among these are the use of nets and trawls, booms, automated image acquisition systems, and visual observations, each with distinct advantages and disadvantages for sampling[11]. Despite this wide range of available sampling techniques, few harmonized methods exist to measure and report floating litter[11]. Thus, there is a clear need for simple, cost-effective ways to measure and compare litter loads between sites and over time.

This chapter outlines the protocols for monitoring floating litter in rivers or estuaries (defined here as rivers with a tidal influence) using visual observations to monitor macro-litter[14] and a specially designed net – the STOP (Survey Technique for Observing Plastic) net, developed by the Sustainable Seas Trust (SST) to monitor litter >2 mm. The STOP net consists of a 2 x 1 m frame and a net with a 2 mm mesh size and is particularly effective in monitoring litter between 2 mm and 25 mm. The large frame allows more litter to be sampled compared to smaller nets and trawls which have the shortcoming of limiting the amount of water (and thus litter) sampled– especially when sampling macro-litter[15]. It has been found that nearly 90% of litter sampled in the upper 1 m of the river water column was found up to 0.5 m below the water surface[12]. The height of the STOP net is therefore sufficient to capture a large portion of floating litter at the surface of the water. A 2 mm mesh size is ideal for capturing meso- and micro-litter and is used for consistency and comparability with data collected in other habitats described in this manual.

7.2. Site selection criteria

1. Description of study site – Surveys should be conducted from bridges above rivers or estuaries; **Figure 7.1**). If there are no bridges within the area, then sampling can be carried out from an anchored boat in the main current of the river.

2. Safety precautions and consideration for natural ecosystems – Surveys should not be conducted at sites where sampling may pose a risk to surveyors, nor where there are endangered or protected habitats and species. Furthermore, surveys should not pose a threat to river vessels or disrupt local fauna and flora.

3. Access to sites – Sites should have clear, year-round access for surveyors. The appropriate permits or authorization should be obtained from the relevant authorities where necessary.

4. Clean-up activities by third parties – No regular public clean-up activities should take place upstream of the study site. If potential sites are regularly cleaned, surveyors should make the appropriate arrangements with local authorities to ensure that study sites are not cleaned during a river study (unless this is directly related to the research question).

5. General site characteristics required:

- The river/estuary must be wide and deep enough for sampling nets (2 m x 1 m) to be submerged and to gain accurate data from flow meters (if used).
- Bridges where monitoring will take place must be structurally secure and have designated pedestrian walkways for safety purposes. Lower bridges are preferred for safety and to enable surveyors to readily observe and identify floating litter with minimal equipment (e.g., ideally without the need to use binoculars).
- The river's flow rate must be fast enough to have water moving into and through the sampling net, but slow enough not to create a backpressure which prevents litter from entering the net.

6. Study site selection – Potential upstream sources of litter must be a consideration in site selection. Several sites should be chosen for comparison, in accordance to the specific questions being asked and answered. These could include various sites within the same river, or sites in different rivers. Random site selection may not be possible, as sites will likely need to vary in proximity to a landfill, to urban areas, commercial areas, industrial areas, etc., depending on the research question. In such instances, site selection should be guided by knowledge/expectations of the amount and type of litter that may be found at a site (based on the factors mentioned above), without first visiting the site to investigate litter loads. Ideally, all study sites should be sampled simultaneously (on the same day), or at least during a small temporal window.

*Please contact SST if there is any uncertainty regarding the study site requirements.

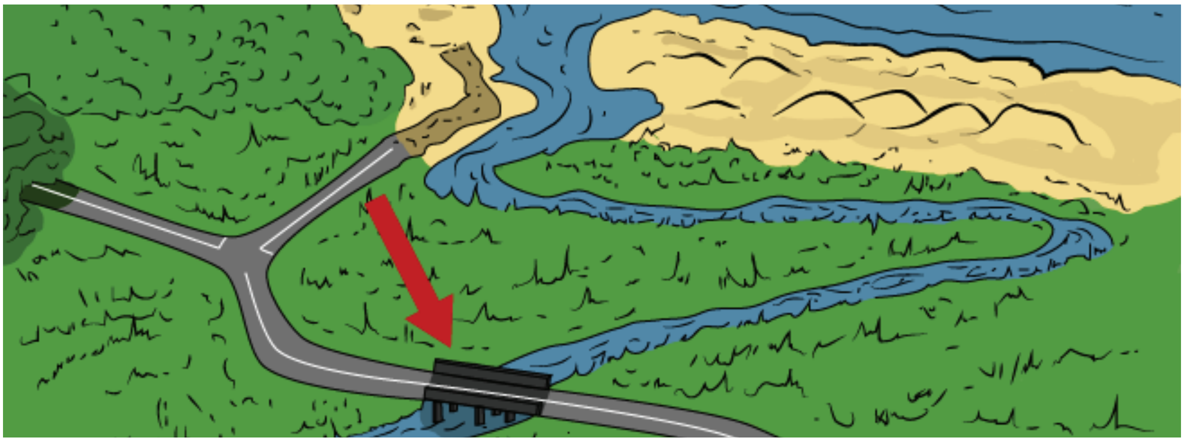


Figure 7.1: Litter surveys in rivers and estuaries are conducted from bridges (indicated above) or from anchored boats within the river flow.

7.3. Equipment list


1. Writing equipment and clipboards


2. Datasheets 4-7


3. Camera


4. GPS device or cellphone


5. Measuring tape (50 m)


6. Weights (to lower the measuring tape into the water)


7. STOP net


8. Flow meter or stick/orange peel


9. Stopwatch


10. Work gloves


11. Bags/containers to collect litter


12. Bucket & clean brush


13. Scales (0.1 g & 0.1 mg resolution)


14. Stackable sieves OR framed sieves with mesh sizes of 2 mm & 25 mm

7.4. Protocol

The STOP net protocol involves using a specialized net (2 m x 1 m), designed by SST to collect floating litter >2 mm flowing down a river (see more details below). This litter size range includes micro-litter (2–5 mm), meso-litter (5–25 mm) and macro-litter (>25 mm). The net should be lowered into a river from a bridge or anchored boat and left to collect litter for 30 min. When the litter collection has been completed, the net will be removed from the river, emptied and the litter stored for further analyses. This will include the categorization, counting and weighing of litter. To optimize sampling efficiency, promote comparability with other studies, and for more accurate estimates of floating litter loads, it is recommended to combine the STOP net technique with visual observations of floating litter (see **7.4.4. Visual Observation of Floating Litter**). It is recommended that river surveys should be repeated daily for 10 consecutive days, to account for the influence of environmental conditions and other factors that may influence daily estimates of litter loads. These surveys should be timed to coincide with rainfall events where possible. See **Appendix 10** for a brief field guide for litter surveys in rivers and estuaries.

Note that certain aspects of the sampling protocol are flexible and may be adapted to answer specific research questions and to ensure that the surveys are feasible when resources are limited. To ensure comparability of results on a large scale, guidelines are presented for adapting protocols by providing three basic approaches to river/estuary surveys (see **Table 7.1**). The minimum requirements for a reliable river/estuary survey are provided in the Bronze Standard approach, while the preferred method is highlighted in the Gold Standard approach.

Table 7.1: Suggested approaches for river surveys given the available resources at the surveyors' disposal and level of pollution at the study site.

	Gold Standard	Silver Standard	Bronze Standard
Method used	STOP net + Visual observations	STOP net + Visual observations	Visual observations
Sampling duration	30 min	30 min	≤30 min (at the surveyor's discretion)
Consecutive days of sampling	10	5-10	5
Size of litter to survey	**STOP net**: >2 mm **Visual observations:** >25 mm	**STOP net:** >2 mm **Visual observations:** >25 mm	**Visual observations:** >25 mm
Categorization and counts of litter	Yes	Yes	Yes
Litter weights	Yes	Yes	No
Weighing individual pieces of litter	Yes	No. Weight is determined per litter type (e.g. lollipop sticks)	N/A

7.4.1. Set up at the study site

1. Rivers in Africa, as in many other parts of the world, have varied water flow characteristics depending on the prevailing climate. Some, known as perennial rivers, flow consistently throughout the year; others, known as periodic rivers, flow well in wet seasons and poorly in dry seasons. Episodic rivers are a third type, for which the seasons are not clearly defined as wet or dry periods, but flow when sporadic rains occur and may cease flowing or have a low flow between rains. Episodic rivers tend to be in semi-arid or arid areas and may have rain at any time of the year. Generally, the rains that sustain episodic rivers are of short duration, sometimes only an hour or so, and range from drizzle to storms, each affecting river flow differently.

To monitor plastics in rivers, it is necessary to measure and compare plastic loads in slow and fast flow periods. This is relatively easy to plan for in rivers that flow consistently and in those with well-defined seasonal flows. In the case of episodic rivers, however, researchers need to be opportunistic and always be prepared to rapidly respond to rain events. All sampling, whether of high or low flows, should be over a 10-day period.

2. Where study sites are influenced by the ocean tides, as in the case of estuaries, sampling should take place three hours after high tide as measured at the site, i.e., when the river flow is at its strongest. This will provide a clear idea of how much litter is flowing down with the river, instead of litter coming in from the ocean with the tide.

3. Ideally, observations should be conducted at the point of the river with the strongest flow, (which should contain most of the litter). This point will usually be on the outside of a bend where the water flow is fastest (**Figure 7.2**).

4. Sampling with the STOP net is not possible in winds stronger than 20 km/h, as the nets become hard to handle and litter blows out of the nets. A new net design is currently in development at SST, to prevent the loss of litter in heavy winds.

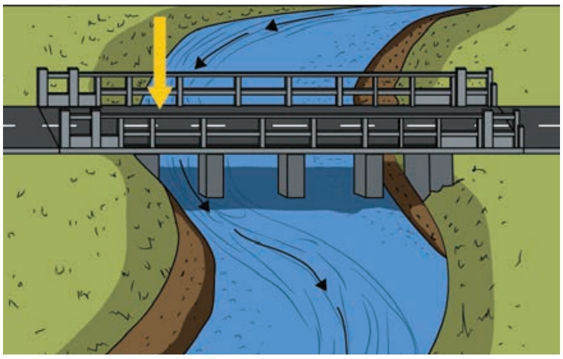


Figure 7.2: Observations should be conducted from the point of the river with the strongest flow.

7.4.2. Site description

Once an appropriate study site has been selected and demarcated, study-site information should be recorded (**Figure 7.3**). Please see **Datasheet 6** for the information required for the study site description (e.g., major land-use, the nearest town, etc.). This datasheet should only be completed once per survey. In contrast, daily changes in site conditions (e.g., weather, wind speeds, water depth, water flow rate) need to be recorded on **Datasheet 7** every time the site is surveyed. Information regarding some aspects of the site descriptions is provided below.

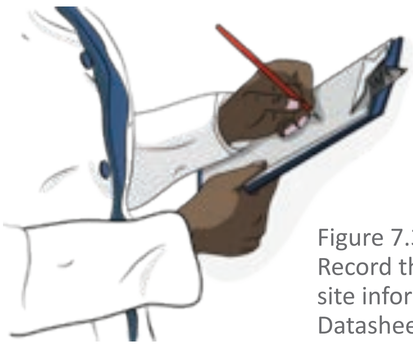


Figure 7.3: Record the study site information in Datasheet 1.

7.4.2.1. Determination of river flow rate

The river flow rate needs to be measured daily during the survey and recorded in the site conditions datasheet (**Datasheet 7**). Flow rate can be measured using a flow meter (by placing it on a submerged portion of the net for the duration of the survey) or by means of the stick/orange peel method. When using the stick/orange peel method, flow rate should be measured at the beginning and end of the sampling session. Average flow rate should be calculated for each day of the survey. The stick/orange peel method works as follows:

1. Measure the width of the bridge or length of the anchored boat (assuming the front and back of the boat are positioned parallel to the river flow).

2. Drop a stick/orange peel upriver of the bridge/boat and once it passed the edge of the bridge/boat, start your timer (**Figure 7.4).**

Figure 7.4: River flow rate can be measured using the stick/orange peel methods.

3. Stop the timer as soon as the orange peel or stick is seen on the other side of the bridge/boat.

4. The river flow rate (m/s) is calculated as follows: bridge width/boat length (m) divided by the time (s) for the stick/orange peel to travel to the other side.

$$\textit{Water velocity (m/s)} = \frac{\textit{Bridge width or boat length (m)}}{\textit{Time (s)}}$$

5. See 7.4.6. **Data Analysis** on how river flow rate is incorporated into the calculations of litter flowing down the river per hour.

7.4.2.2. Measuring water depth and bridge height

To measure the water depth and height of the bridge/boat at the observation point, observers should:

1. Lower a weighted measuring tape down to the water surface and record the height of the bridge/boat (**Figure 7.5**). These measurements should be made from eye level to measure the observation height for visual surveys (see **7.4.4. Visual Observation of Floating Litter**)

2. After doing so, keep the measuring tape in the same position and lower the weights down to the bottom of the river and measure again. The height to the surface of the water should be subtracted from the height to the bottom of the river to determine water depth.

Figure 7.5: Use a weighted measuring tape to measure water depth and observation height.

7.4.3. Net deployment

1. Open the net and place the net squarely on the ground before clicking the frame together (**Figure 7.6**). You will note that one of the connections on the frame has an anti-twist section to prevent the frame from twisting. There are green ropes (used to keep the frame in place), yellow ropes (attached to the top of the frame that will be at the water's surface) and red ropes (attached to the bottom of the frame and will be used to 'scoop' up the litter when the net is pulled up). Weights have been attached to the bottom of the frame, to ensure that the frame remains weighed down when placed in the water.

Figure 7.6: To assemble the STOP net, open the net, place it squarely on the ground, and click the frame together. Note that there is an anti-twist section on one side of the frame to prevent the frame from twisting.

2. Pass the green ropes around the opposite ends of the frame from where they are attached and tie them firmly to ensure that the frame cannot fall apart (**Figure 7.7**). Make sure to not make the ropes overly tight, otherwise you will distort the frame. In addition to holding the frame, the ropes also prevent the net's contents from inverting in the wind.

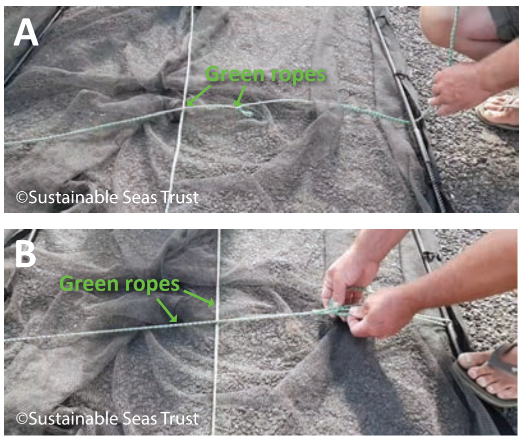


Figure 7.7: A) Pass the green rope around the opposite end of the frame and B) tie them firmly to ensure that the frame cannot fall apart. Make sure to not make the ropes overly tight, otherwise you will distort the frame.

3. Clear all your ropes away from the net, untangling them and laying them neatly out on the ground, ready for deployment (**Figure 7.8**).

4. Tie the ends of the upper two ropes (coloured yellow) securely to the bridge (**Figure 7.9**).

Figure 7.8: Clear all your ropes from the net, to ready it for deployment.

Figure 7.9: Tie the upper two ropes (coloured yellow) securely to the bridge.

5. Lower the frame (using the yellow ropes) from the downwind side of the bridge (**Figure 7.10**). This will ensure that the content of the net does not get blown out when the net is pulled up at the end of the sampling time. Note that sometimes the flow direction of the river may prevent the deployment of the net on the downwind side of the bridge, as a strongly-flowing river may drag the net underneath the bridge – out of the observers' line of sight. The net should always be visible to ensure that it remains in position for the duration of the survey. Therefore, one must ensure that the net is deployed in limited wind conditions (especially when it cannot be deployed on the downwind side of the bridge), so the content of the net does not get blown out when the net is pulled up. Be sure to keep hold of the red ropes while you are lowering the net.

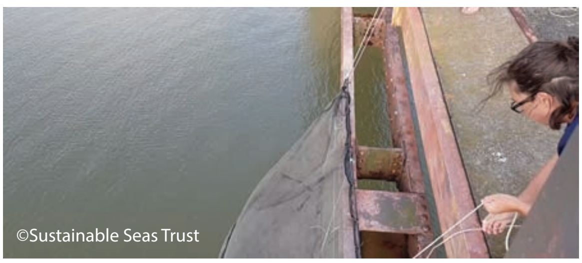


Figure 7.10: Lower the frame (using the yellow ropes) from the downwind side of the bridge. Be sure to keep hold of the red ropes while you are lowering the net.

6. Once the net is at the appropriate height (i.e., with the net below the water and the top of the frame at the surface of the water), adjust the red ropes to ensure that the net is perpendicular to the river surface (**Figure 7.11**).

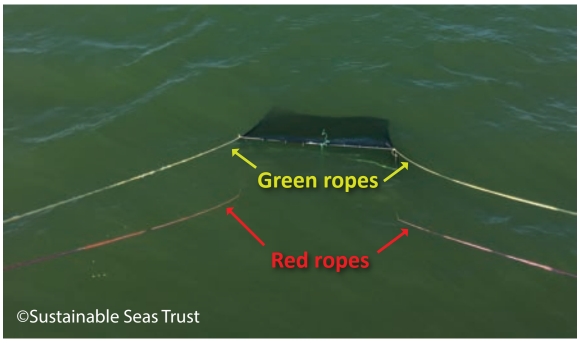


Figure 7.11: Once the top of the frame is at the appropriate height at the surface of the water, adjust the red ropes to ensure that the net is perpendicular to the river surface.

7. Tie the ropes securely to the bridge to keep the net in place until the end of the sampling session. The flow of the river and influence of the tide may cause the frame to change position during the survey. In such instances, be sure to adjust the ropes as required to keep the net in position (i.e., perpendicular to the water surface) for the duration of the survey.

7.4.4. Sample collection

1. Once the STOP net has been deployed, start the stopwatch, and record the starting time in **Datasheet 7**. The net should then be monitored over a 30 min sampling period. If the net is filled with litter before 30 min have passed, stop your timer, lift the net as described under **3. STOP net recovery** below, collect and store its contents and put it back in the water. Once back, resume the timer, so that the net is consistently deployed and trapping litter for a total time of 30 min. During the survey, the ropes of the net should be adjusted (if required) to make sure that the net stays in the correct position with regards to the riverbed and river flow.

2. Visual observation of floating litter:

a. For the most accurate estimates of litter loads in rivers, we recommend combining the STOP net technique, with visual observation of floating macro-litter (>25 mm) at the surface of the water.

These techniques will provide two estimates of macro-litter loads in the river. If surveyors are using both techniques, it is required to start the visual observations of floating litter as soon as the net is in position in the water.

b. The protocol for visual observation of floating litter requires surveyors to observe and record all visible litter >25 mm that is floating near the surface of the water along the entire river width[14] (**Figure 7.12**). If observers are unable to feasibly observe litter for the entire width of the river, then observations should take place within the width of the river with the fastest flow (as with the STOP net technique; **Figure 7.12**). Be sure to record the width of the river surveyed in **Datasheet 7**. For 30 min, observers will record the amount and type of litter floating past their vantage point.

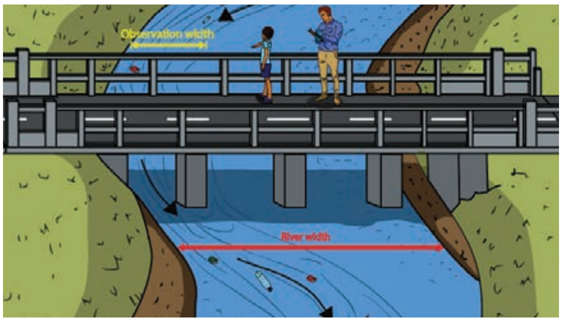


Figure 7.12: Visual observations of floating litter should be conducted along the entire length of the river. If this is not feasible, then observations should be made at the point in the river where the flow is strongest.

c. Visual observations of floating litter should be performed from elevated positions (e.g., from bridges, piers, etc.). Therefore, when river flow surveys are performed from boats, some bias may be expected as surveyors will likely not see litter as easily as from a higher vantage point. To reduce this bias, observers should conduct visual observations of litter from the highest available safe place on the boat. Binoculars may be necessary to identify floating litter. Note that local river characteristics and weather conditions may influence the observers' ability to see litter floating on the river surface.

d. **Datasheets 6 and 7** should be completed for the study site description and daily site conditions (if this has not already been completed for the STOP net survey). Observations of litter should be recorded in **Datasheet 4** (separately from the STOP net results).

3. STOP net recovery:

a. After 30 min of deployment time, lift the net up by pulling on the bottom two ropes (coloured red) to lift the base of the net up to the river surface ('scooping' up any litter; **Figure 7.13**). Lifting the base of the net first will ensure one does not lose the contents of the net. Be sure to leave the ropes fastened to the bridge as the net is pulled from the water.

b. To retrieve the net from the water, pull on all 4 ropes simultaneously (red and yellow ropes). This will ensure that the contents of the net are not lost during the retrieval process.

c. Once the net is on the bridge, place it on a tarpaulin/canvas or similar material in a safe area, away from traffic.

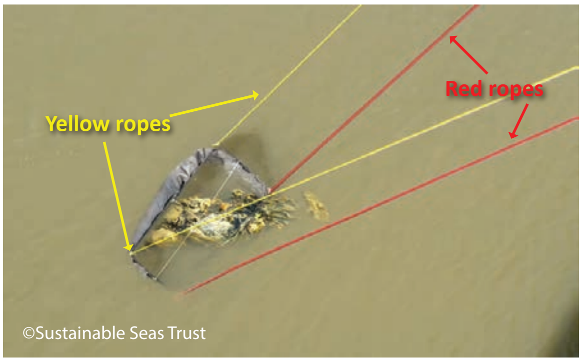


Figure 7.13: To 'scoop' up the litter, pull on the bottom two red ropes.

4. Once the net is open on a tarpaulin/canvas, easily identifiable pieces of litter can be collected by hand or with forceps and placed into containers/bags (**Figure 7.14**). Note that macro-litter (>25 mm) and smaller litter (2–25 mm) will be analysed separately and can thus be separated in the field to save time. Easily identifiable non-litter items (e.g., vegetation, animals, rocks etc.) should be discarded at the site if appropriate or at an alternative appropriate location. When removing organic material, be sure to check if any small pieces of litter may be entangled in the material.

Figure 7.14: Retrieve litter from the net.

5. Once the easily identifiable items have been removed/collected, the remaining materials in the net should ideally be further sorted at the site (if the weather conditions are suitable and if litter loads are not too high) to separate litter from non-litter items, or the collected materials can be placed in a separate bag/container for sorting in the lab at a later stage. Collection bags/containers should be clearly labelled to include the study site name, and date and time of collection.

6. After sampling is complete, deconstruct the net and tidy up the area. Dismantling the net is simply a reversal of the construction process.

7.4.5. Laboratory Analysis

7.4.5.1.Separating litter from non-litter items

Upon returning to the laboratory or to an appropriate location for analyses of the litter, litter should be separated from other material by hand or with forceps (if this was not completed in the field). However, it may be hard to differentiate small litter items <25 mm from non-litter materials. The following steps to separate litter from non-litter items are recommended:

1. Dispose of all the identifiable non-litter/natural items >25 mm that are easily removed.

2. Sieve the remaining material through stacked sieves with mesh sizes of 25 mm and 2 mm (**Figure 7.15**). In this manual, items are sorted according to their longest dimension, but sieving sorts items according to their shortest dimension. For example, items (e.g., long, thin fibres) with a width <2 mm and length >2 mm may fall through a 2 mm sieve but should still be collected for the survey. Special care should thus be taken to collect litter items that have dimensions >2 mm that may have fallen through the sieves. Litter on top of the 25 mm sieve is classified as macro-litter and can be stored and processed separately from smaller litter (see 7.4.5.2 **Macro-litter processing** for instructions on how to collect data for macro-litter). The material on top of the 2 mm sieve is transferred to containers or bags for further processing (see 7.4.5.3 **Meso-litter processing** section). Litter that falls through the bottom sieve with the 2 mm mesh is not studied here and can be responsibly discarded.

Figure 7.15: After removing all visible non-litter items, sieve the remaining material through stacked sieves with 25 mm and 2 mm mesh

7.4.5.2. Macro-litter processing

1. Each piece of macro-litter must be cleaned and dried before weighing. Biological material such as animals and seaweed that may influence weight measurements should be removed during the cleaning process (**Figure 7.16**). Where possible, clean brushes (e.g., paintbrushes) can be used to remove soil from dry objects. Note that some items, such as sponges, are easier to clean when dry. Brushes may also be used to remove hard-to-reach soil in the folds and corners of the litter. Alternatively, packets and bags may be turned inside-out or torn carefully along the seams (without breaking the litter into more pieces) to remove soil that accumulates in the corners. Hygiene and sanitation items such as condoms, sanitary pads, tampons and diapers need not be washed or cleaned for weighing. Weights of clean, dry proxies should be used in such cases. Proxies are optional for clothing or other fabric.

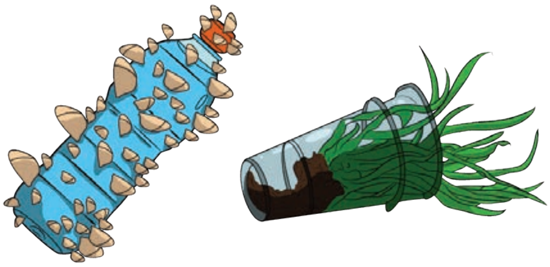


Figure 7.16: Biological material should be removed from litter during the cleaning process.

2. All pieces of macro-litter must be counted and categorized into litter types as per the litter datasheet (**Datasheet 4**). See **Appendix 3** for a visual guide to the macro-litter categories and Box 7.1 for more information about how to process the litter after cleaning it. **Appendix 4** may be used to sort litter fragments into different size classes as required for **Datasheet 4** (**Figure 7.17**).

Figure 7.17: Appendix 4 can be used to sort macro-litter fragments into different size classes as required.

3. Before weighing the litter, surveyors should ensure that all items are dried properly. Items such as fabric and cigarette butts may take longer to dry. Litter should be weighed per type of litter item to the nearest 0.1 g, i.e., not necessarily for all individual pieces of litter (**Figure 7.18**). For example, surveyors may have collected 112 lollipop sticks with a total weight of 56.0 g. Some heavier items may require a different scale with a 1 kg resolution. Hooks, sinkers, lures and other fishing equipment should be removed from fishing lines and weighed in their respective litter categories.

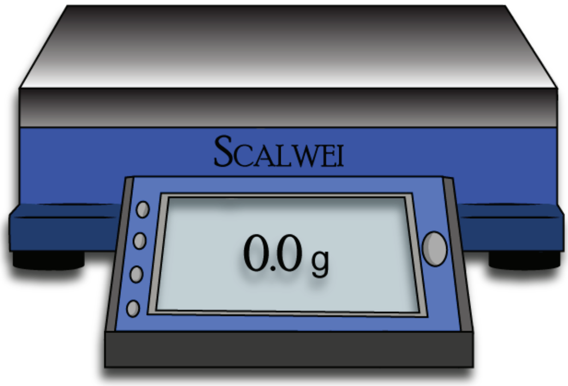


Figure 7.18: Macro-litter should be weighed per type of litter to the nearest 0.1 g.

*Optional: Depending on the research question and the available resources, each piece of litter may be weighed individually to provide information regarding litter fragment weights. For identical complete items (e.g., earbuds), an average weight per item may be used and multiplied by the number of complete pieces. However, unique and/or fragmented items should be weighed individually when surveyors are concerned with the individual weights of items.

Box 7.1. Guidelines for categorization of macro-litter

1. How to categorize fragments of litter:

If fragments are recognizable as being part of a larger item, then it should be recorded as that item. For example, if a fragment of a beverage bottle (see image) can clearly be identified as such, then it should be counted and weighed as a beverage bottle. However, if there is doubt regarding the origin of the fragment, it should be categorized as a fragment according to its properties e.g., 'Plastic fragment – hard (2.5 – 5 cm)' or 'Metal fragment (10 – 25 cm)'.

2. How to count multiple fragments originating from a single item:

If multiple fragments have been collected that can be matched to the same origin (e.g., a single torn sweet packet), it should be recorded as separate fragments, as it would have dispersed separately if not collected. Additionally, it may be hard to keep track of litter fragments when working with large quantities of litter. However, if litter items are torn or broken during or after collection, they should be recorded as one item.

3. How to record entangled items:

If multiple items of litter are entangled, they should be untangled wherever possible and recorded separately (unless otherwise indicated).

4. How to record items consisting of multiple litter types:

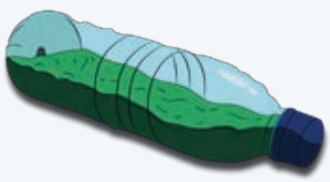
Where litter items from different categories are collected as part of one entity, it should be recorded as the dominant litter type by weight. For example, if a plastic beverage bottle with a bottle cap and drink label is collected, it should be recorded as 'Bottle – Beverage' under the 'Plastic Objects' category. Similarly, a wooden beam with nails embedded will be recorded as a wooden beam.

5. How to categorize an item that is not listed in the datasheet:

If an item is encountered that does not fit into a listed litter type or category, take a photograph, and describe and record it in the 'Others' section as 'Item Name (Material Type)' – for example: 'Matchbox (Cardboard)'.

6. How to weigh items that contain liquids:

If an item contains liquids, the contents should be poured out before weighing. However, if there are safety concerns regarding disposal of the liquid, then an empty proxy of the same type of container can be weighed.



4. Brand audits: Brand audits may be completed for litter collected on each day of the survey.

By counting and categorizing branded litter found during clean-ups of polluted sites, information can be obtained regarding the type and origin of litter. Brand audits are recommended for every litter survey. Here we present protocols adapted from the '#BreakFreeFromPlastic' official brand audit protocols. '#BreakFreeFromPlastic' has developed a protocol to conduct plastic brand audits on a global scale. The coalition gathers the results of global brand audits to compile a report highlighting the brands and types of plastics commonly found at clean-ups around the world. To maximize the impact of clean-ups, it is recommended that official brand audits are submitted to the '#BreakFreeFromPlastic' website. It should be noted that there are some key differences between the protocols presented here and that of '#BreakFreeFromPlastic'. The primary goal of brand audits in the context of this manual is to obtain information regarding the source of the litter and the persistence of litter in the environment.

The official '#BreakFreeFromPlastic' protocols have thus been modified to include all litter (as opposed to just plastic) and to only include branded items with the relevant information to answer the research questions stated above. Surveyors interested in performing the official '#BreakFreeFromPlastic' plastic brand audit should therefore visit their official website, for more information and to ensure that they collect the appropriate information, at https://www.breakfreefromplastic.org/brandauditoolkit/.

Brand audits can be performed on litter from standing-stock surveys or on the litter collected on Day Zero of an accumulation survey. To facilitate brand audits, branded and non-branded litter may be separated during clean-ups. After collection, each piece of branded litter should be counted and categorized as per the brand audit datasheet (**Datasheet 3**). Information regarding the brand name, manufacturer, source of the litter (local or foreign), type of product, type of material, type of layers (for plastic items), and date manufactured or best before (BB) dates (when date manufactured is not available) are required for each piece of branded litter (**Figure 7.19**). Where possible, the location of sale can be recorded for receipts or other items. A visual guide (**Appendix 2**) is available to aid in identifying the type of product and packaging for each piece of litter recorded.

Figure 7.19: Information regarding the brand name, manufacturer, date manufactured, and source of the litter that can be found on branded items.

The product source is defined here as the country where the product was most likely discarded (as opposed to just the country of manufacture). Some products may be imported from foreign countries (e.g., China), then bought and thrown away locally. In such instances, especially for litter washing up on seashores, the origin of the litter is uncertain. It is necessary therefore to identify items manufactured elsewhere but sold locally. Brand audits from litter surveys on land, or in rivers/estuaries are useful to compile a master list of branded items which are known to be sold/found locally.

When the packaging is fragmented or stained and not all required information is visible, available information should be recorded as per the brand audit datasheet and "N/V" recorded for information not visible. Information regarding the manufacturer and source of the litter can be researched if the brand is known. Only items that include at least one of the following need to be incorporated into the brand audit: 1) brand, 2) manufacturer, 3) source of the litter, 4) date of manufacturing, and/or 5) best before date. Items without this information, therefore, do not need to be included in the brand audit. However, if surveyors are interested in a more comprehensive survey that also includes non-branded items, then information regarding types of products and material can also be included in brand audits, even when the previously mentioned information is not available (as is the case in the official 'BreakFreeFromPlastic' brand audit).

7.4.5.3. Meso-litter processing

1. Easily identifiable pieces of litter between 2 and 25 mm can be collected by hand or with forceps for further analysis. To minimize the risk of overlooking small plastic items, all remaining debris should be added to a 20 L bucket of saltwater (as this makes it easier to collect litter). If saltwater is not available, then freshwater can also be used, but surveyors should ensure that they inspect the material at the bottom of the bucket carefully for litter at the end of this process. Most plastic fragments are less dense than water and float, making it easier to collect them.

Solid plastic particles made from polymers with a greater density than water do not float but can be detected by vigorously stirring the water in the bucket, causing high-density plastics to swirl around in the water for longer than non-litter items such as shell or stone (**Figure 7.20**). These floating fragments of litter can be collected by hand or with forceps. Alternatively, a small net with a 2 mm mesh can be used to catch floating plastics in the swirling water. Be sure to inspect the bottom of the bucket for any additional litter. The remaining materials (e.g., soil, shells and stones) that do not qualify as litter should be discarded in an appropriate manner.

Figure 7.20: Meso-litter particles floating in a bucket of swirled water. The floating meso-litter particles can easily be collected, while items such as stones sink to the bottom of the bucket faster than the plastic particles.

2. Litter between 2 and 25 mm should be sorted into appropriate fragment size categories as per **Datasheet 5** (i.e., 2–5 mm, 5–10 mm, and 10–25 mm). Sieving is not advised on its own to separate litter items into specific size categories, since it sorts items by their smallest dimension. It is therefore recommended to perform sieving (using sieves with mesh sizes of 2 mm, 5 mm, 10 mm) as an initial step to sort fragments rapidly, but to then confirm the sorting by manually measuring fragments by hand using diagrams such as the one shown here (**Figure 7.21**). Alternatively, grids of different sizes may be used to sort items according to fragment size (**Appendix 6**). This sorting of items may also be completed after all items have been washed (see Step 3a).

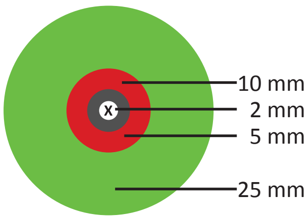


Figure 7.21: Diagram of circles with varying diameters (to scale) that can be used to sort litter items between 2 and 25 mm into size categories.

3. After litter pieces have been separated from other materials, all litter pieces must be:

a. Cleaned with water or brushes to remove any remaining soil and/or biological material that may influence weight measurements.

b. Air-dried, to ensure that all items are dry before weighing. Note that some pieces of litter such as fabric may require more time to dry than others.

c. Counted and categorized as per the meso-litter datasheet (**Datasheet 5**). See Appendix 7 for a visual guide of meso-litter categories.

d. Weighed per category (e.g., "Ropes/Fibres") to the nearest 1 mg/ 0.001 g.

Optional: If researchers are interested in weights of meso-litter fragments, pieces of litter can be weighed individually. If pieces in the same category weigh <1 mg (e.g. foam fragments), it is recommended to weigh a cluster of 10 or 20 pieces together and calculate (and record) the average weight for those fragments.

7.4.5.4. Discarding litter

1. Once the survey is complete, litter should be disposed of correctly, ideally for recycling, or stored for further analysis (**Figure 7.22**). Biodegradable organic waste can be composted, and recyclable materials can go to recycling and/or material recovery facilities.

Figure 7.22: Litter should be disposed of correctly after the survey is completed.

7.4.5.5. Sampling schedule

For river or estuary surveys, repeat the daily survey at the same location for 10 consecutive days. Note that separate site conditions (**Datasheet 7**) and litter datasheets (**Datasheets 4 & 5**) need to be completed for each day of the survey. The frequency of sampling will depend on the research question. If the focus is on establishing litter baselines and monitoring changes over time, then quarterly surveys (i.e., every three months) may be sufficient. However, if small changes in litter loads are of concern, then more frequent sampling will be necessary.

7.5. Data analysis

Litter loads should be calculated as a total (i.e., all litter), per litter size (e.g., >25 mm, 10–25 mm, 5–10 mm, and 2–5 mm), per litter category (e.g., plastic), and/or per litter type (e.g., lollipop sticks). This will allow surveyors/researchers to compare broader results (per category and in total) between sites and over time, while also being able to detect changes in the number and weight of litter items over time. The latter is important to inform and monitor the effectiveness of litter reduction methods. Results will also be comparable with surveys on land, along shorelines, and/or in mangroves.

The number and weight of items will be calculated per cubic metre of water, which will be determined from the water flow rate and the size of the net. The formula below can be used to calculate litter loads in river:

$$\textit{litter.m}^{-3} = \frac{\textit{Litter collected (per hour)}}{\textit{Net area x Flow rate x 3600}}$$

Where:
Litter collected = the number or weight of litter items collected in the sampling net per hour of sampling. For example, if 50 pieces of litter was collected in a 30 min sampling session, then 50 x 2 = 100 pieces of litter would have been collected in an hour.
Net area = the area (length multiplied by the width) of the mouth of the sampling net where litter enters. The area of the 2 m x 1 m STOP net is 2 m^2.
Flow rate = the rate (in metres per second) at which the water flows into the net – as measured using the stick/orange peel method.

7.5.1. Example of litter sampled in a river using the STOP net

Assuming:

Net area: **2 m^2**	Flow rate: **1.4 $m.s^{-1}$**	Number of litter items collected in one hour: **100 $items.h^{-1}$**

The formula above can be used to calculate the number of litter items found per unit of water sampled:

$$\frac{100}{2 \times 1.4 \times 3600} = 0.01 \text{ items.m}^{-3}$$

The formula calculates the amount of water passing through the net within a given time and then divides the amount of litter found in that same time by the amount of water sampled.

7.5.2. Using measures of litter loads to estimate the amount of litter flowing to the ocean

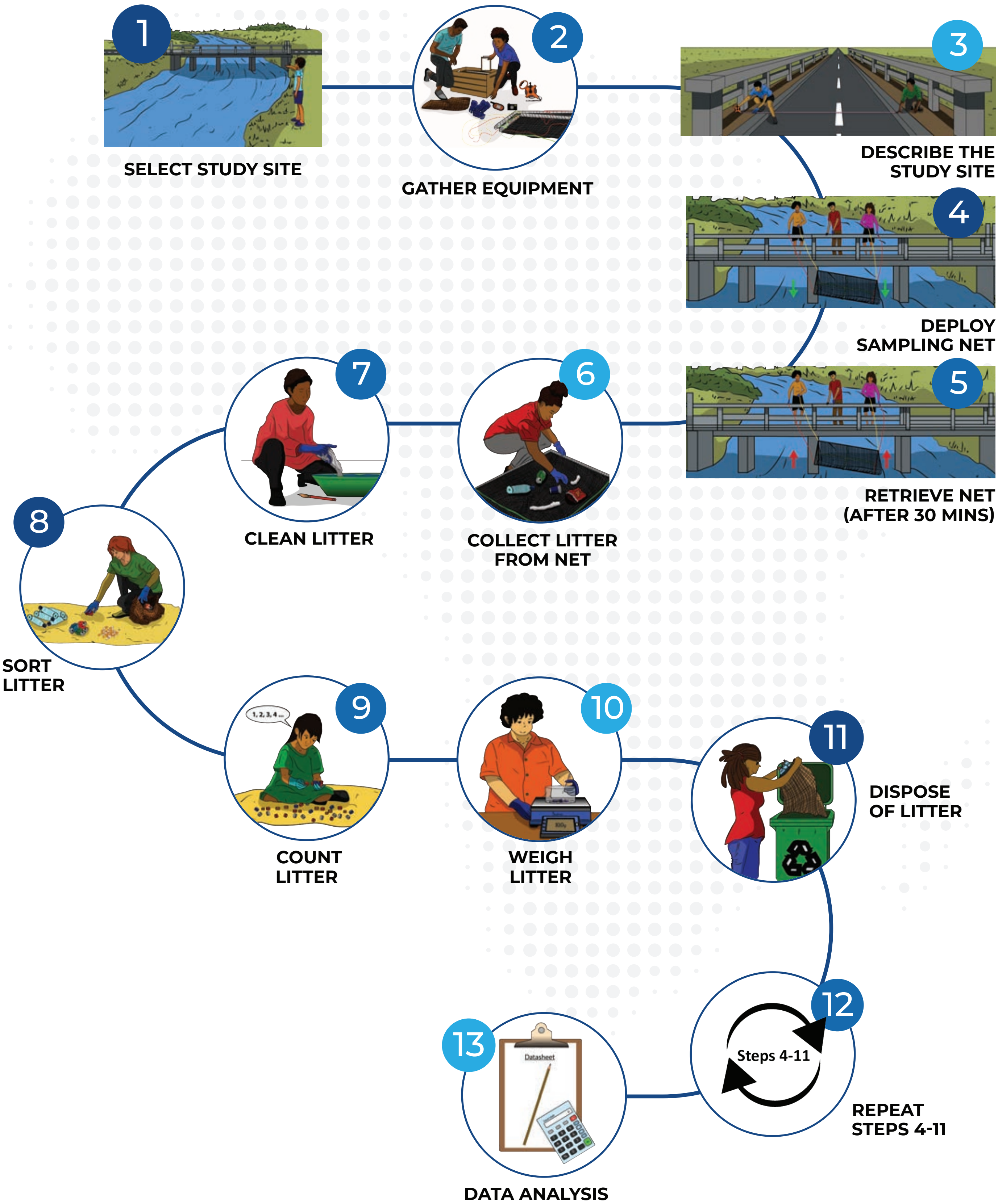
Assuming:

Discharge of hypothetical river: **170 $m^{-3}.s^{-1}$**	Number of litter items collected per cubic metre of water: **0.01 $items.m^{-3}$**

Then the amount of litter theoretically flowing into the ocean from that river is:

$170\ m^3.s^{-1} \times 0.01\ items.m^{-3} = 1.7$ litter $items.s^{-1}$. This amounts to 6 120 pieces of litter entering the ocean every hour, 146 880 pieces per day and 54 million pieces per year.

Protocol for litter monitoring in rivers and estuaries



Chapter 8

Macro-litter monitoring on land

Toshka Barnardo, Peter G Ryan & Lorien Pichegru

Chapter 8

8.1. Introduction

Most marine litter is predicted to originate from land-based sources[1]. In order to reduce marine litter, pollution is best addressed at source, before it reaches stormwater outlets, rivers, and eventually the ocean. Furthermore, litter pollution on land has economic, social, health, and environmental repercussions[2,3]. Litter monitoring is therefore required to identify litter hotspots, estimate the composition and abundance of litter, identify sources of litter, and guide litter reduction measures on land. Additionally, when combined with other monitoring efforts in rivers, along shorelines, and/or at sea, litter monitoring on land can aid in obtaining more accurate estimates of the sources of marine litter and the leakage of litter into the marine environment.

Land-based litter is currently not well-studied, and data are lacking on the distribution and abundance of litter on land, especially in Africa[3,4]. Important research questions that may be addressed with litter monitoring on land include: 1) where are the litter hotspots on land; 2) what are the major sources of litter pollution on land; 3) what are the amounts and types of litter found on land; 4) how is the litter being transported to the sea? Answering these questions is of great importance in order to understand and manage inputs into aquatic ecosystems.

Identifying and monitoring litter hotspots on land (e.g., streets, schools, parks, recreational sport areas, etc.) on a regular basis can be very useful in understanding the influence of various factors such as land-use type, density of development, socio-economic circumstances, income level, demographics, and religion on litter loads. Understanding these dynamics contributes to the design of appropriate litter management methods to stop litter at source[5,6]. Additionally, when used in conjunction with remote sensing and Geographic Information System (GIS) technology, litter surveys on land can aid in identifying routes from source to sea, as well as in estimating the type and proportion of land-based litter entering aquatic systems. This will help with comprehending the origin of litter on the shore and at sea.

Standardized methods to assess litter on land are lacking. However, standing-stock surveys and accumulation surveys, as described in Chapter 3, are useful methods to estimate the amounts and types of litter in different environments. Here, we adapted the methods described in the previous chapters to be applicable to litter surveys on land.

8.2. Site selection criteria

1. Description of study site – Macro-litter surveys on land may be conducted within non-linear habitats (e.g., parking lots, school yards, parks, and fields) and/or along linear habitats (i.e., road verges).

2. Safety precautions and consideration for natural ecosystems – Surveys should not be conducted at sites where sampling may pose a risk to surveyors, nor where there are endangered or protected species and habitats.

3. Access to sites – Sites should have clear, year-round access for surveyors.

4. Clean-up activities by third parties – Sites should have no regular public clean-up activities. If sites are regularly cleaned, surveyors should make the appropriate arrangements with local authorities to ensure that study sites are not cleaned during an accumulation study.

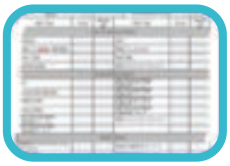
5. Study site dimensions – Study sites need to fulfil the minimum length requirement of the specific survey. Depending on the litter loads, research questions and/or available resources, study sites may vary greatly in size. Linear study sites of at least 200 m are recommended. If the length requirements cannot be accommodated at the study site, the largest available area should be used and the site dimensions (length and width) carefully recorded. Similarly, if one is working in heavily polluted areas in which waste accumulation is rapid and litter loads high, it may be necessary to sub-sample, i.e., reduce the transect length. The minimum sampling area in non-linear habitats will depend on the research question and/or available resources and should therefore be decided at the discretion of the surveyors and recorded accordingly. Guidelines for selection of study-site length and other important factors are provided in **Table 8.2**.

6. Study site selection – Several sites should be chosen for comparison, in accordance to the specific question to be answered. Random site selection may not be possible, as sites will likely need to vary in terms of land-use type (e.g., rural areas, urban areas, commercial areas, industrial areas), neighbourhood characteristics (e.g., demographics, socio-economic circumstances, income level), and proximity to sources of litter, depending on the research question. In such instances, site selection should be guided by knowledge/expectations of the amount and type of litter that may be found at a site (based on the factors mentioned above), without first visiting the site to investigate litter loads. Ideally, all study sites should be sampled simultaneously (on the same day), or at least during a small temporal window.

*Please contact SST if there is any uncertainty regarding the study site requirements.

8.3. Equipment list


1. Writing equipment and clipboards


2. Datasheets 2,3,8 & 9


3. Demarcation flags/signs


4. Camera


5. GPS device or cellphone


6. Measuring tape (50 m)


7. Work gloves


8. Bags/containers to collect litter


9. Environmentally friendly paint/markers


10. Bucket & clean brush


11. Scales (0.1 g & 1 kg resolution)

8.4. Standing-stock survey

Standing-stock surveys are conducted at a single point in time (e.g., over a single day). The protocol for these surveys is like that of accumulation surveys (see below). For differences between standing-stock surveys and accumulation surveys, see **Table 8.1**). Visible macro-litter (>25 mm) on the ground is collected, cleaned, categorized, counted, and weighed. Smaller items such as cigarette butts and caps/lids should also be included, since these are commonly littered. Site description, site condition, brand audit (optional), and macro-litter datasheets (**Datasheets 2, 3, 8, and 9**) need to be completed for standing-stock surveys.

Table 8.1: Basic differences between standing-stock surveys and accumulation surveys.

	Standing-stock survey	Accumulation survey
Removal of litter	Optional	Mandatory
Number of sampling days	1 day (normally)	7 consecutive days (recommended)
Type of data that can be collected	• Litter density • Litter weight • Types of litter	• Litter accumulation rate (count & weight) • Types of litter
Advantages	Quick, easy, cheap	More reliable data

8.5. Accumulation survey

8.5.1. Protocol

The basic protocol for an accumulation survey includes an initial Day Zero clean-up of all visible macro-litter on a predetermined study site, followed by daily clean-ups of the site for a recommended 7 consecutive days. After each day, accumulated litter is collected to be cleaned, categorized into predetermined litter types (as per datasheets), and then counted and weighed. At the end of an accumulation survey, surveyors will be able to calculate the number and weight of litter accumulating per metre (m^{-1}) or square metre (m^{-2}) per day. See **Appendix 10** for a brief field guide for macro-litter accumulation surveys on land.

Note that certain aspects of the sampling protocol are flexible and may be adapted to answer specific research questions and to ensure that the surveys are feasible when resources are limited. To ensure comparability of results on a large scale, guidelines are presented for adapting protocols by providing three basic approaches to accumulation surveys (see **Table 8.2**). The recommended minimum requirements for a reliable accumulation survey are provided in the Bronze Standard approach, while the recommended method is highlighted in the Gold Standard approach. Examples of study-site lengths have been provided here, but surveyors may select alternative suitable transect lengths based on their site characteristics, pollution level, and available resources. By calculating litter loads per metre, surveyors can select a custom study-site length, while ensuring that results are still comparable with those of other studies.

Table 8.2: Suggested approaches for macro-litter accumulation surveys on land given the available resources at the surveyors' disposal and level of pollution at the study site.

	Gold Standard	Silver Standard	Bronze Standard
Transect length in linear habitats	>500 m (may vary depending on the street length, research questions, and/or resources)	200–500 m (may vary depending on the street length, research questions, and/or resources)	200 m (may vary depending on the street length, research questions, and/or resources)
Transect width in linear habitats	Varies according to verge width	Varies according to verge width	Varies according to verge width
Study area size in non-linear habitats	Varies according to research question	Varies according to research question	Varies according to research question
Consecutive days of sampling	7	3–7	3
Size of litter to survey	**>25 mm**	**>25 mm**	**>25 mm**
Day zero initial clean-up	**Yes**	**Yes**	**Yes**
Litter count	**Yes**	**Yes**	**Yes**
Litter weight	**Yes**	**Yes**	**Optional**
Weighing individual pieces of litter	Yes	No. Weight is determined per litter type (e.g., lollipop sticks)	No. Weight is determined per litter type (e.g., lollipop sticks)

8.5.1.1. Set up at the study site

Litter surveys in non-linear habitats can be conducted in any area where litter may accumulate, e.g., school yards, parking lots, public parks, and taxi ranks (**Figure 8.1**). In comparison, surveys in linear habitats are conducted along road verges. Typical road verges can be identified as a distinct strip of gravel/vegetation/concrete directly adjacent to the carriageway/roadway (**Figure 8.2**). Sidewalks may be included in the study area at the discretion of the surveyor. In cases where verges are very wide, surveyors may sample a portion of the verge and record the width sampled. Surveyors may sample one or both sides of the road.

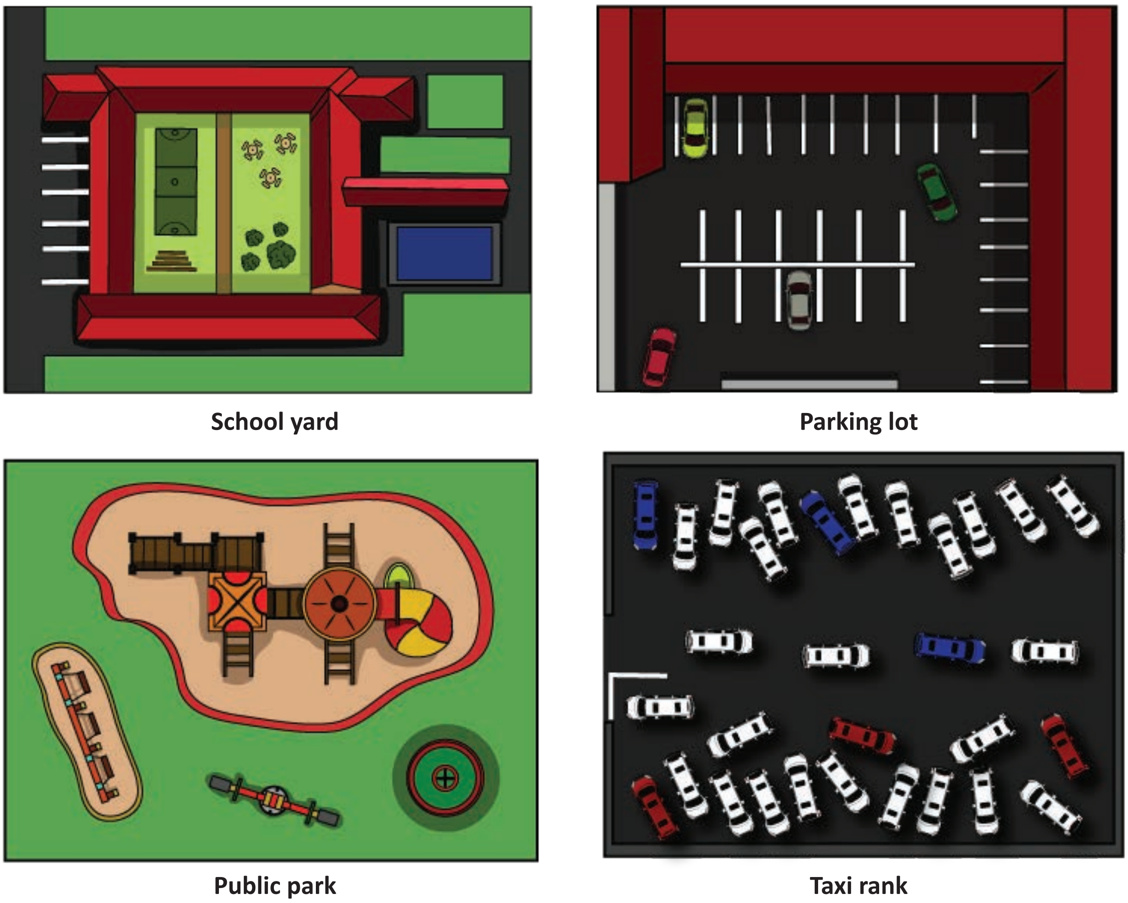


Figure 8.1: Litter surveys can be conducted in any area where litter may accumulate. Examples of areas to survey include school yards, parking lots, public parks, and taxi ranks.

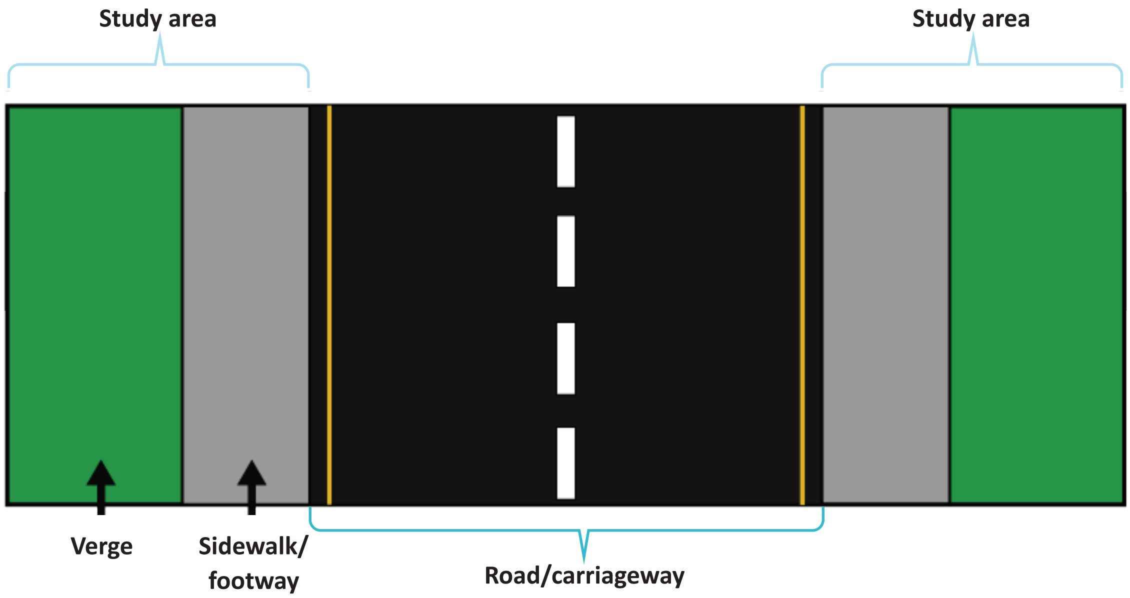


Figure 8.2: Street litter surveys are conducted along road verges and may include the sidewalk.

GPS readings should be taken at the boundaries of the study site to ensure that the same site is surveyed in the future. This is especially important where only a portion of a habitat is sampled (e.g., only one side of a street or a portion of a parking-lot). Added confirmation can be derived from locating the sites in relation to local permanent landmarks (specific shops or houses, traffic/street signs, big rocks, trees, or other structures).

8.5.1.2. Site description

Once an appropriate study site has been selected and demarcated, study-site information should be collected and recorded (**Figure 8.3**). Please see **Datasheet 8** for the information required for the study-site description (e.g., GPS coordinates for the start and end of the transect, site width, land-use type, etc.). This datasheet should only be completed once per survey. In contrast, site conditions (e.g., weather and wind speeds) need to be recorded on **Datasheet 2** each time the site is surveyed. Information regarding some aspects of the site descriptions is provided below.

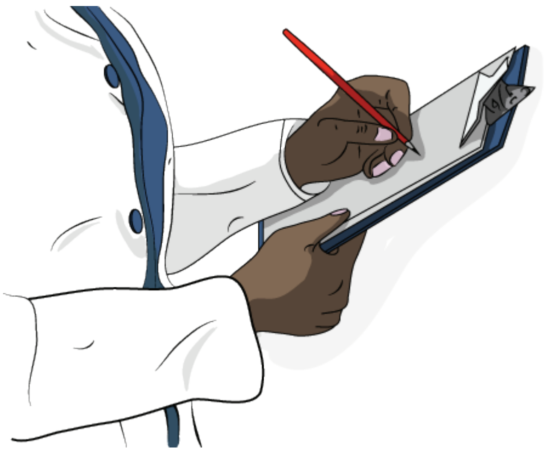


Figure 8.3: Record the study site information in Datasheets 2 & 8.

Measuring verge width

To determine the average verge width (m) along the transect, the width should be determined at regular intervals along the transect and averaged. It is recommended to have at least five width measurements evenly spaced along a transect. Since verge width may vary throughout the transect, surveyors may also decide on a predetermined set width to be sampled (e.g., 3 m).

8.5.1.3. Day Zero clean-up/ Standing-stock surveys

Prior to beginning a new accumulation study, all visible litter (>25 mm) on the surface or protruding from the surface should be removed from the study site in an initial clean-up event (defined here as the Day Zero clean-up). Smaller items such as cigarette butts and caps/lids should also be included, since these are commonly littered. Litter collected during an initial clean-up of the study area can be used for a standing-stock survey but should not be incorporated into an accumulation survey. A clean study area with zero litter is required before daily litter accumulation can be measured.

The immediate vicinity around the study area should be cleaned to ensure that accumulation estimates are not influenced by lateral movement of litter. It is recommended to walk in a planned pattern (to be determined at the discretion of the surveyors) when collecting litter. It is recommended that at least one person, 'The Sweeper', follows behind the rest of the surveyors to ensure that the entire site has been thoroughly cleaned.

8.5.1.4. Brand auditing

By counting and categorizing branded litter found during clean-ups of polluted sites, information can be obtained regarding the type and origin of litter. Brand audits are recommended for every litter survey. Here we present protocols adapted from the '#BreakFreeFromPlastic' official brand audit protocols. '#BreakFreeFromPlastic' has developed a protocol to conduct plastic brand audits on a global scale. The coalition gathers the results of global brand audits to compile a report highlighting the brands and types of plastics commonly found at clean-ups around the world. To maximize the impact of clean-ups, it is recommended that official brand audits are submitted to the '#BreakFreeFromPlastic' website. It should be noted that there are some key differences between the protocols presented here and that of '#BreakFreeFromPlastic'. The primary goal of brand audits in the context of this manual is to obtain information regarding the source of the litter and the persistence of litter in the environment. The official '#BreakFreeFromPlastic' protocols have thus been modified to include all litter (as opposed to just plastic) and to only include branded items with the relevant information to answer the research questions stated above. Surveyors interested in performing the official '#BreakFreeFromPlastic' plastic brand audit should therefore visit their official website, for more information and to ensure that they collect the appropriate information, at https://www.breakfreefromplastic.org/brandaudittoolkit/.

Brand audits can be performed on litter from standing-stock surveys or on the litter collected on Day Zero of an accumulation survey. To facilitate brand audits, branded and non-branded litter may be separated during clean-ups. After collection, each piece of branded litter should be counted and categorized as per the brand audit datasheet (**Datasheet 3**). Information regarding the brand name, manufacturer, source of the litter (local or foreign), type of product, type of material, type of layers (for plastic items), and date manufactured or best before (BB) dates (when

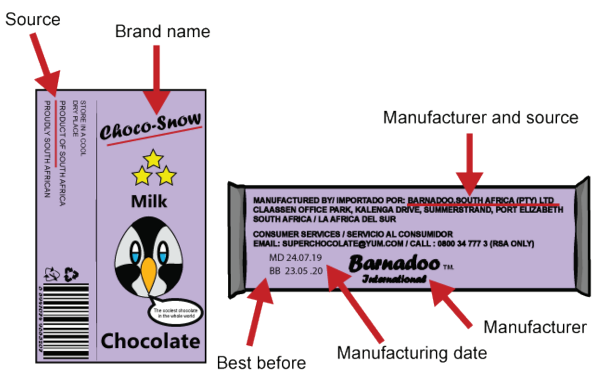


Figure 8.4: Information regarding the brand name, manufacturer, date manufactured, and source of the litter that can be found on branded items.

date manufactured is not available) are required for each piece of branded litter (**Figure 8.4**). Where possible, the location of sale can be recorded for receipts or other items. A visual guide (**Appendix 2**) is available to aid in identifying the type of product and packaging for each piece of litter recorded.

The product source is defined here as the country where the product was most likely discarded (as opposed to just the country of manufacture). Some products may be imported from foreign countries (e.g., China), then bought and thrown away locally. In such instances, especially for litter washing up on seashores, the origin of the litter is uncertain. It is necessary therefore to identify items manufactured elsewhere but sold locally. Brand audits from litter surveys on land are useful to compile a master list of branded items which are known to be sold/found locally. This list could help determine the source of litter washing up on shorelines and reduce the uncertainty and potential bias regarding the source of beach litter.

When the packaging is fragmented or stained and not all required information is visible, available information should be recorded as per the brand audit datasheet and "N/V" recorded for information not visible. Information regarding the manufacturer and source of the litter can be researched if the brand is known. Only items that include at least one of the following need to be incorporated into the brand audit: 1) brand, 2) manufacturer, 3) source of the litter, 4) date of manufacturing, and/or 5) best before date. Items without this information, therefore, do not need to be included in the brand audit. However, if surveyors are interested in a more comprehensive survey that also includes non-branded items, then information regarding types of products and material can also be included in brand audits, even when the previously mentioned information is not available (as is the case in the official 'BreakFreeFromPlastic' brand audit).

8.5.1.5. Accumulation survey sample collection

1. Daily surveys of the study area should be conducted by walking in a planned pattern – especially in large, non-linear habitats. It is recommended to use a parallel walking pattern and to divide the study area among surveyors. The precise walking pattern used to survey the area is not as important as ensuring that the entire study area is surveyed thoroughly and cleared of all accumulated litter.

2. Every piece of litter encountered should be collected for analysis in the laboratory (**Figure 8.5**). In the spirit of reducing single-use plastic waste, it is recommended that, wherever possible, surveyors should use reusable bags/containers to collect daily litter. Collection bags/containers should be clearly labelled to include the study-site name, and date of collection.

Figure 8.5: Collect every piece of litter on the surface or protruding from the surface.

3. If an item of litter is too large to be removed (e.g., large appliances, car parts, and construction material), make a clear, recognizable mark (e.g., using paint) on the item (**Figure 8.6**). This prevents the object from being counted in subsequent surveys. An alternative is to photograph it and note the locality. Heavy or large items should be recorded, counted and weighed where possible. If items are too heavy to weigh, the mass may be estimated by 1) measuring the dimensions of the object (using a measuring tape), 2) calculating the volume of the object, and 3) multiplying volume by density of the type of material. The density of materials can be found on the internet. To facilitate mass calculations at a later stage, be sure to record the type of material alongside the type of item in the datasheet (e.g., 'Refrigerator [Plastic]').

Figure 8.6: To prevent counting the same items twice, make a clear, recognizable mark (e.g., using paint) on items that are too large to be removed from the study site.

4. Potentially dangerous items such as chemicals, weapons, and ammunition should be recorded and counted but not handled (**Figure 8.7**). The relevant authorities should be notified of any potentially dangerous items. It is recommended that the item be photographed, and the locality noted to avoid counting the object in subsequent surveys. The mass of potentially dangerous items should be estimated as previously mentioned in point 3 – estimating the volume of the object and multiplying by the density of the material. For medicines, items may be collected, and the weight estimated, but the contents should not be handled.

Figure 8.7: Potentially dangerous items should be recorded and counted but not handled.

8.5.1.6 Laboratory analysis/ Litter processing

1. Upon returning to the laboratory, or to an appropriate location for analysis of the litter, each piece of litter must be cleaned for weighing. Some soiled or dirty items may need to be rinsed in a bucket of water and air-dried. Where possible, clean brushes (e.g., paintbrushes) can be used to remove soil from dry objects. Hygiene and sanitation items such as condoms, sanitary pads, tampons and diapers need not be handled further. Weights of clean, dry proxies should be used instead. The same applies to dirty clothing or other fabric.

2. All pieces of macro-litter must be counted and categorized into litter types as per the litter datasheet (**Datasheet 9**). See **Appendix 3** for a visual guide to the macro-litter categories and **Box 8.1** for more information about how to process the litter after cleaning it. **Appendix 4** may be used to sort litter fragments into different size classes as required for **Datasheet 9** (**Figure 8.8**).

Figure 8.8: Appendix 4 can be used to sort litter fragments into different size classes as required.

Before weighing the litter, surveyors should ensure that all items are dried properly. Items such as fabric and cigarette butts may take longer to dry. Litter should be weighed per type of litter item to the nearest 0.1 g (**Figure 8.9**). For example, surveyors may have collected 112 lollipop sticks with a total weight of 56.0 g. Some heavier items may require a different scale with a 1 kg resolution.

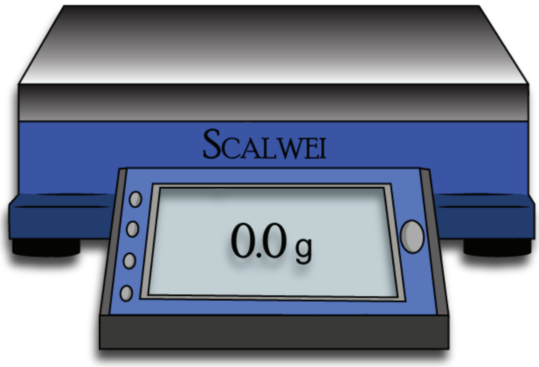


Figure 8.9: Litter should be weighed per type of litter to the nearest 0.1 g.

Box 8.1. Guidelines for categorization of macro-litter

1. How to categorize fragments of litter:

If fragments are recognizable as being part of a larger item, then it should be recorded as that item. For example, if a fragment of a beverage bottle (see image) can clearly be identified as such, then it should be counted and weighed as a beverage bottle. However, if there is doubt regarding the origin of the fragment, it should be categorized as a fragment according to its properties e.g., 'Plastic fragment – hard (2.5 – 5 cm)' or 'Metal fragment (10 – 25 cm)'.

2. How to count multiple fragments originating from a single item:

If multiple fragments have been collected that can be matched to the same origin (e.g., a single torn sweet packet), it should be recorded as separate fragments, as it would have dispersed separately if not collected. Additionally, it may be hard to keep track of litter fragments when working with large quantities of litter. However, if litter items are torn or broken during or after collection, they should be recorded as one item.

3. How to record entangled items:

If multiple items of litter are entangled, they should be untangled wherever possible and recorded separately (unless otherwise indicated).

4. How to record items consisting of multiple litter types:

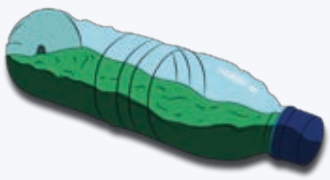
Where litter items from different categories are collected as part of one entity, it should be recorded as the dominant litter type by weight. For example, if a plastic beverage bottle with a bottle cap and drink label is collected, it should be recorded as 'Bottle – Beverage' under the 'Plastic Objects' category. Similarly, a wooden beam with nails embedded will be recorded as a wooden beam.

5. How to categorize an item that is not listed in the datasheet:

If an item is encountered that does not fit into a listed litter type or category, take a photograph, and describe and record it in the 'Others' section as 'Item Name (Material Type)' – for example: 'Matchbox (Cardboard)'.

6. How to weigh items that contain liquids:

If an item contains liquids, the contents should be poured out before weighing. However, if there are safety concerns regarding disposal of the liquid, then an empty proxy of the same type of container can be weighed.



3. Once the survey is complete, litter should be disposed of correctly, ideally for recycling, or stored for further analysis (**Figure 8.10**). Biodegradable organic waste can be composted, and recyclable materials can go to recycling and/or material recovery facilities.

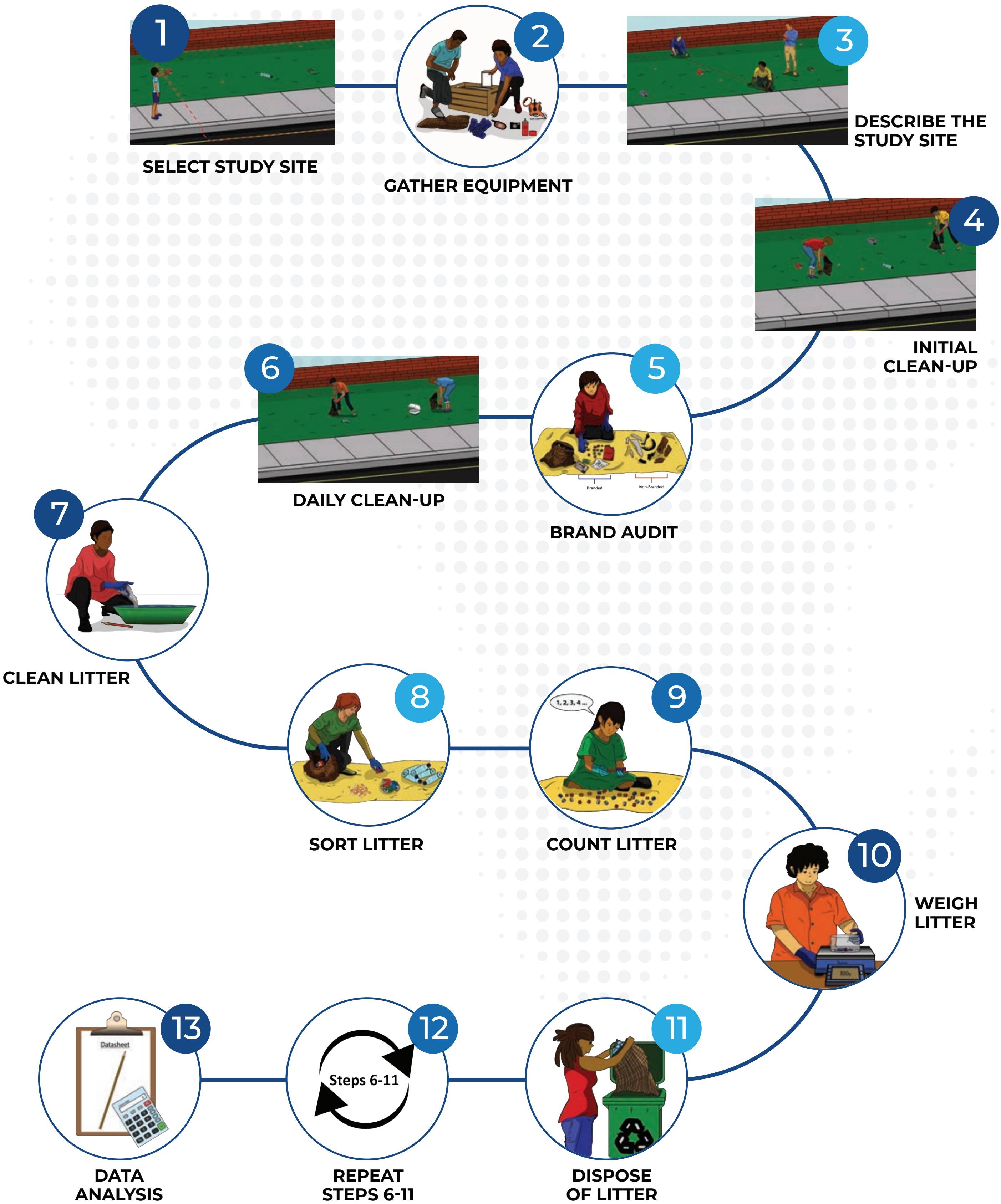
Figure 8.10: Litter should be disposed of correctly after the survey is completed.

4. For accumulation surveys, repeat the daily survey across the same site for 7 consecutive days after the initial clean-up. Please note that new datasheets for site conditions and litter need to be completed for each day of the survey. The frequency at which surveys are conducted will depend on the research question. If the focus is on establishing litter baselines and monitoring changes over time, then quarterly surveys are recommended. If small changes in litter loads are of concern, then more frequent surveys will be necessary.

8.6. Data analysis

For linear habitats, the total number and weight of items will be calculated per 100 metres for standing-stock surveys (e.g., 5 items.100 m^{-1} or 20.0 g.100 m^{-1}) and per 100 metres per day for accumulation surveys (e.g., 2 items.100 m^{-1}.day and 0.5 g.100 m^{-1}.day). For non-linear habitats, calculation will be per square metre for both standing-stock (e.g., 5 items.m^{-2} and 20.0 g.m^{-2}) and accumulation surveys (e.g., 2 items.m^{-2}.day and 0.5 g.m^{-2}.day). For both types of surveys, the number of items and weight should be calculated as a total (i.e., all litter), per category (e.g., plastic), and per litter type (e.g., lollipop sticks). This will allow surveyors/researchers to compare broader results (per category and in total) between sites and over time, while also being able to detect changes in the number and weight of litter items over time. The latter is important to inform and monitor the effectiveness of litter reduction methods.

Protocol for macro-litter monitoring on land



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Appendix 1

FIELD GUIDE FOR MACRO-LITTER ACCUMULATION SURVEYS

White boxes may be used to tick which steps have been completed

STEP 1: FIND A STUDY SITE

Study sites should be located along a shoreline and may be any length depending on the beach characteristics, the site pollution level, and the resources available to the surveyors. The study site will span from the edge of the water to the back of the beach.

STEP 2: ERECT SIGNS AT THE STUDY SITE

Signs should be erected to indicate that the study area should not be cleaned by third parties for the duration of the survey. These signs could serve as permanent reference points to locate the study site upon return trips.

STEP 3: DESCRIBE THE SITE

Study site descriptions (**Datasheet 1**) and site conditions (**Datasheet 2**) need to be measured and recorded before commencing with any clean-ups or surveying. **Datasheet 1** will only need to be completed once during the duration of the accumulation survey, but **Datasheet 2** will have to be completed daily before commencing with fieldwork.

STEP 4: CLEAN UP THE BEACH

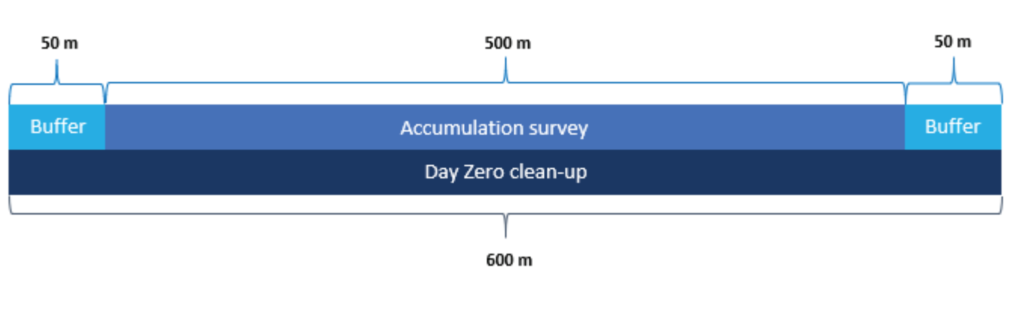
An initial Day Zero beach clean-up is needed before accumulation surveys. This clean-up should be completed along the entire length of the study area where accumulation surveys will be conducted, including 50 m buffers on each side of the transect. For example, if a 500 m transect is used for accumulation surveys, then a 600 m transect should be cleaned on Day Zero. The clean-up should extend from the edge of the water to the back barrier of the beach. These data from Day Zero will not be incorporated into the accumulation study. All visible macro-litter should be removed.

STEP 5: DO A BRAND AUDIT

It is recommended to perform a brand audit on the litter collected during the initial Day Zero clean-up of the study site. A brand audit datasheet (**Datasheet 3**) is provided, and a visual guide (**Appendix 2**) is available to aid in the brand auditing process.

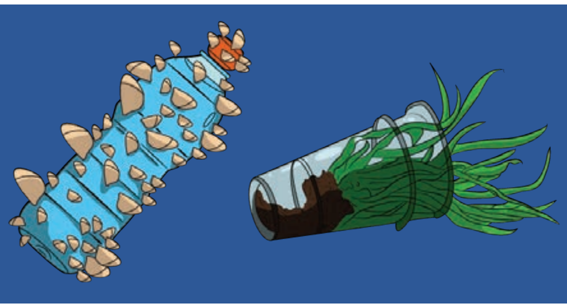
STEP 6: DO A DAILY SURVEY OF STUDY AREA

Within the length of shoreline (e.g., 600 m) cleaned on Day Zero, a smaller area (e.g., 500 m) will be surveyed daily for 10 consecutive days, starting the day after the Day Zero clean-up, to collect any accumulated litter. Buffer zones of 50 m are maintained on each side of the 500 m transect. These buffer zones would have been cleaned on Day Zero and during the survey. Litter collected in the buffer zones should however not be included in the accumulation survey. The figure below illustrates how a study site may be divided along its length.



STEP 7: COLLECT AND SEPARATE ACCUMULATED LITTER

Collect every piece of litter you see. Be sure to separate the litter collected in the intertidal zone (wet sand), from the litter collected in the supratidal zone (dry sand).



STEP 8: WORK IN THE LAB

Clean and dry each piece of litter before weighing. Be sure to remove all sand and/or biological material from the litter items. Every piece of macro-litter needs to be categorized into litter types as per the macro-litter data sheet (**Datasheet 4**), and then counted and weighed per litter type (e.g., earbuds) to the nearest 0.1 g or 1 kg for larger items. **Appendix 3** provides a visual guide to litter classification. **Appendix 4** may be used to sort litter fragments into different size classes. Separate datasheets need to be completed for litter collected in the intertidal and supratidal zones. A separate datasheet should also be used for each day of the survey.

STEP 9: REPEAT STEPS 6 – 8

For accumulation surveys, repeat the daily survey across the same stretch of beach for 10 consecutive days after the initial clean-up. At the end of the study, the number of litter items and/or kg weight per m length of beach per day may be calculated. Once the survey is complete, collected litter must be correctly disposed of or stored for further analysis.

Appendix 2

VISUAL GUIDE FOR BRAND AUDITING

#breakfreefromplastic

Brand Audit Categories

TYPE OF PRODUCT

For every product that you find, try to identify one of the categories below to which it belongs. If the identity of the item is not immediately clear or if it doesn't neatly fit into a category below, you can mark it as 'Other' (that includes things like balloons, pellets, tires, pieces or fragments of larger items, various metal materials, etc.

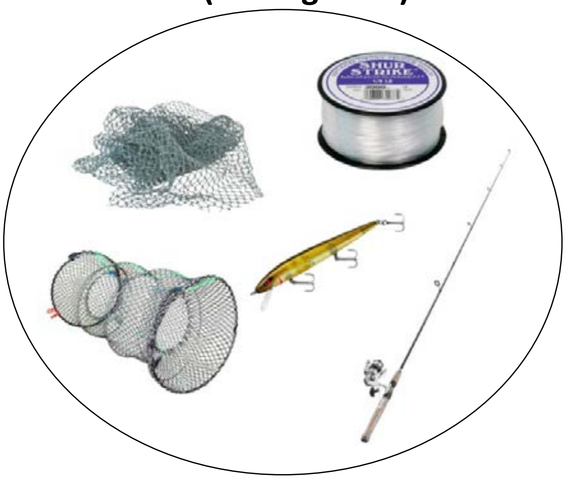
FP (Food Packaging)

HP (Household Products)

PC (Personal Care)

SM (Smoking Materials)

FG (Fishing Gear)



PM (Packing Material)

Appendix 2

#breakfreefromplastic

Brand Audit Categories

TYPE OF MATERIAL

If an item you collect in a clean-up has a visible plastic number on it, identify the plastic type using the handy guide below (PET, HDPE, PVC, LDPE, PP, or PS). Any product marked with a #7 or is not plastics or a type of material hard to identify—like sanitary products, diapers, or textiles - falls under the other category (O).

PET (1)

Polyethylene terephthalate: Clear or tinted plastic; often used for drink bottles, cups, pouches, etc.

HDPE (2)

High-density polyethylene: White or coloured plastic; often used for product bottles, jars, milk jugs, etc.

PVC (3)

Polyvinyl chloride: Durable plastic, hard or rubbery; often used for building materials, toys, shower curtains, etc.

LDPE (4)

Low-density polyethylene: Clear, white, or coloured plastic; often used for bags, plastic trays, holders, dispensers, etc.

PP (5)

Polypropylene: Hard but flexible plastic; often used for food containers or tubs, bottle caps, etc.

PS (6)

Polystyrene: Rigid, brittle plastic OR foam; often used for cups, take-out food containers, lids, etc.

O (7 +)

Other / unknown; bioplastics, products containing other plastics or types of materials, including textiles, etc.

MATERIAL LAYERS

Try your best to identify each product as single–layer (SM) or multi-layer (ML), based on your feel and perception of the material.

SL

Single-layer, flexible plastic film; often used for packaging and wrapping, polythene bags, etc.

ML

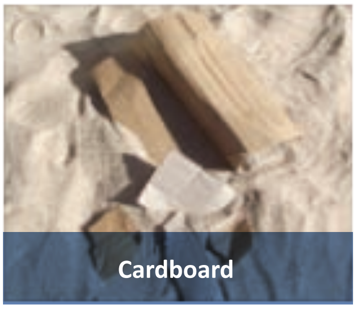
Multi-layer: plastic bonded with another material; often used for sachets, shelf-stable milk and juice boxes, personal care products, etc.

This guide has been extracted with permission from the #BreakFreeFromPlastic website. The website can be accessed at: https://www.breakfreefromplastic.org/.

Appendix 3

VISUAL GUIDE TO MACRO-LITTER CLASSIFICATION

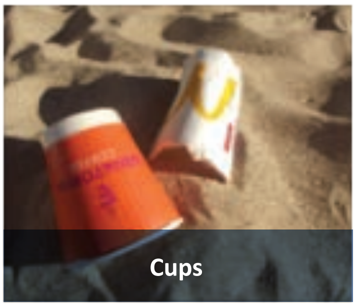
Paper & Cardboard Objects


Cardboard


Carton - Beverages

Carton - Food

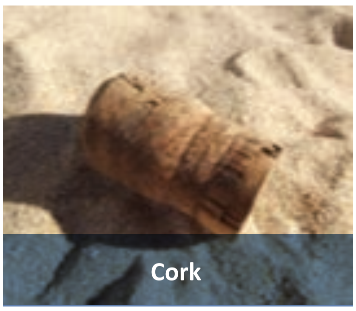

Cigarette Packets


Cups

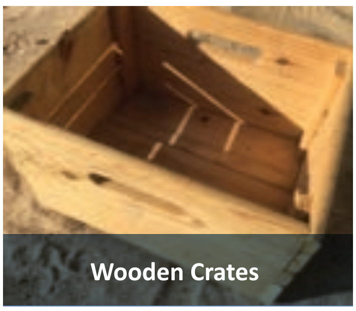

Paper


Paper Bags

Processed Wood Objects


Cork


Ice cream/Ice Lolly Sticks


Wooden Crates

Appendix 3


Wooden Pallets


Processed Wood Fragments

Rubber Objects


Balloons


Rubber Boots


Rubber Gloves


Tyres


Rubber Fragments

Clothing Objects


Clothing

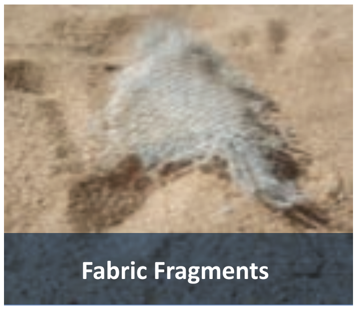

Non-rubber Gloves


Shoes - Flip Flops

Appendix 3

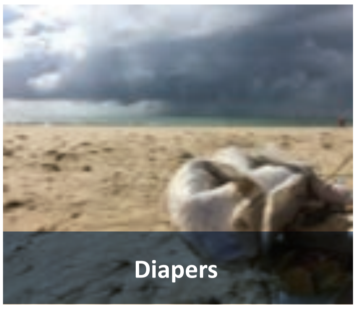

Shoes - Other


String (Cotton)


Fabric Fragments

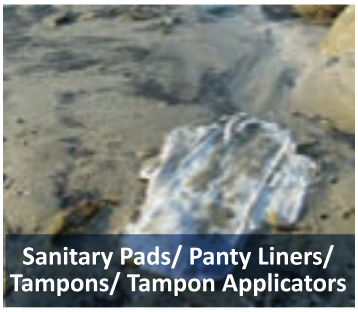
Hygiene Objects


Condoms/Condom Wrappers


Diapers


Earbuds


Medical Containers/ Tubes


Sanitary Pads/ Panty Liners/ Tampons/ Tampon Applicators


Syringes/ Needles

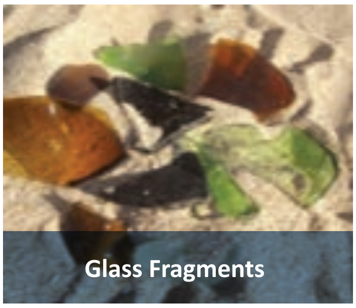

Wet Wipes/ Tissues/ Toilet Paper

Appendix 3

Glass Objects

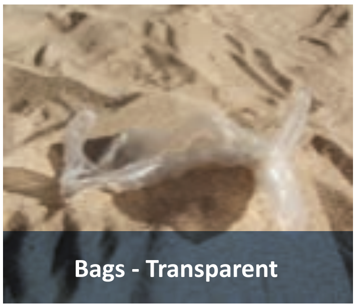

Glass Bottle


Light Bulb/Tube


Glass Fragments

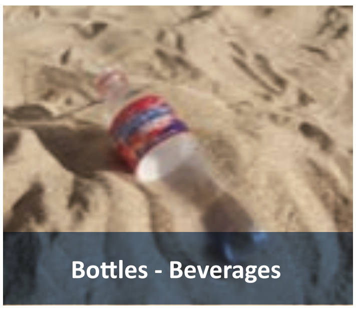
Plastic Objects

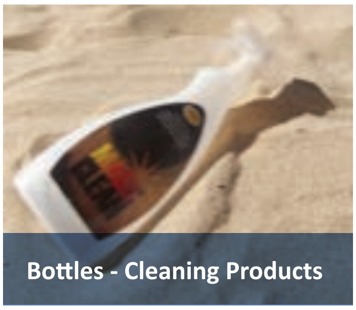

Bags - Shopping


Bags - Transparent


Bags - Woven


Bags - Other


Bottles - Beverages


Bottles - Cleaning Products


Bottles - Cosmetics/Personal Care


Bubble Wrap


Buckets (not single use)

Cable Ties

Caps/Lids/Lid Rings

Carpets/ Laminated Flooring

Cigarette Lighters

Cigarettes

Containers - Cleaning Products

Containers - Cosmetics/Personal Care

Containers - Food

Crates

Cups

Combs/Hair Brushes

Jerry Cans

Lollipop Sticks

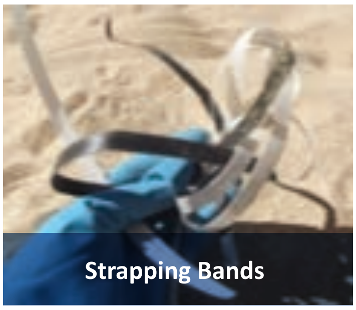
Mesh

Pens/Stationary

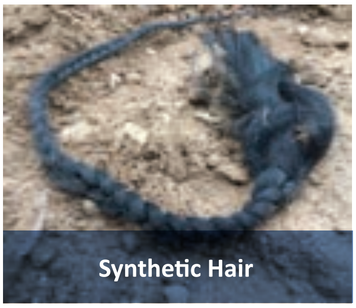
Appendix 3


Plates


Sellotape/ Duct Tape/ Plastic Stickers

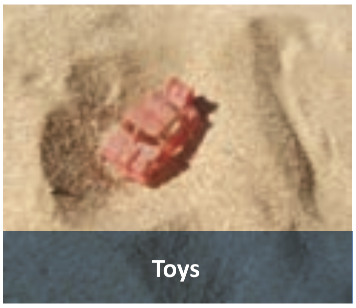

Strapping Bands


Straws

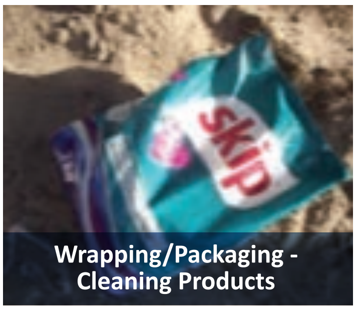

Synthetic Hair


Tarpaulin/Sheeting

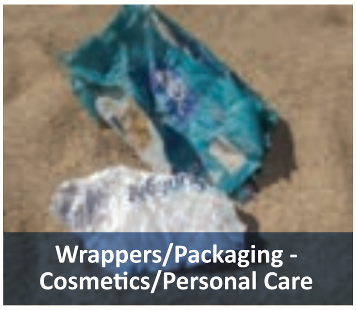

Toothbrush/ Toothpaste tube


Toys

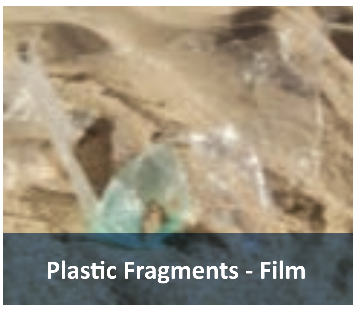

Utensils/Cutlery

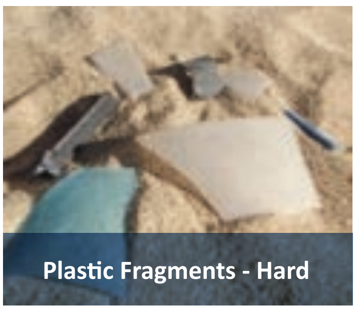


Wrapping/Packaging - Cleaning Products


Wrappers/Packaging - Cosmetics/Personal Care

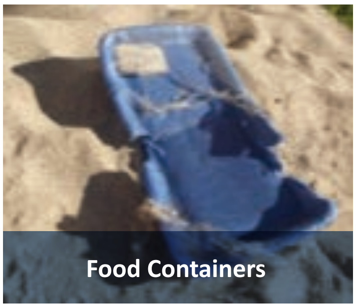

Wrappers/Packaging - Food/Drink


Plastic Fragments - Film


Plastic Fragments - Hard

Appendix 3

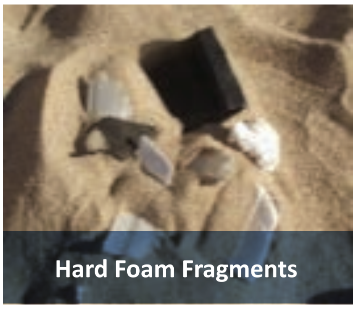
Foam Objects


Food Containers

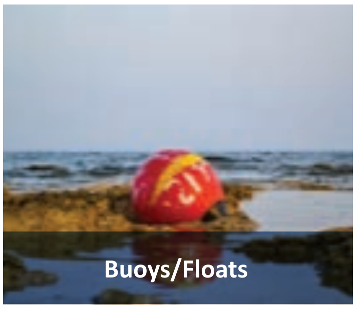

Cups


Cushioning Foam


Soft Foam Fragment


Hard Foam Fragments

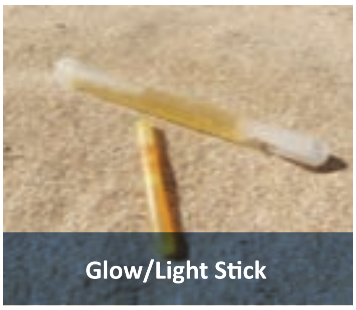
Marine & Fishing Gear


Buoys/Floats


Fishing Line


Fishing Net


Fishing Traps

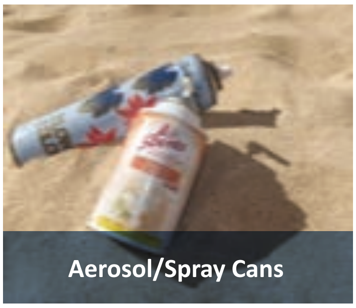

Glow/Light Stick

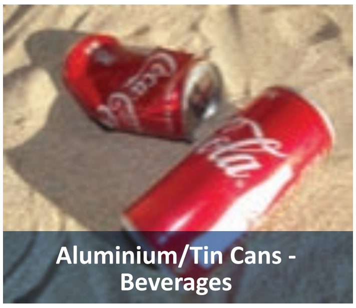

Lures/Jigs/Other Plastics


Rope/String


Sinker/Hook/Other Metals

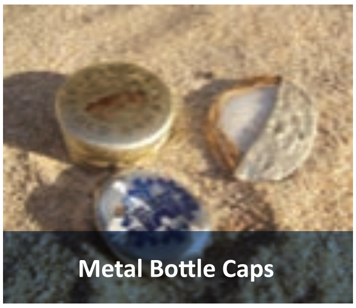
Metal Objects


Aerosol/Spray Cans

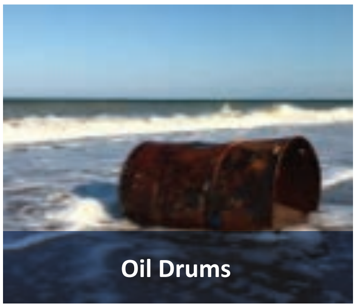

Aluminium/Tin Cans - Beverages

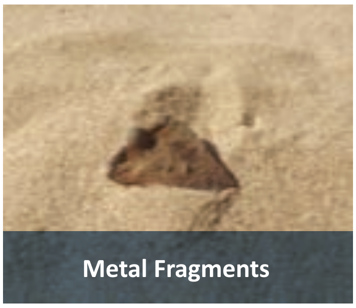

Aluminium/Tin Cans - Food


Foil


Metal Bottle Caps


Metal Wire/Mesh


Oil Drums


Metal Fragments

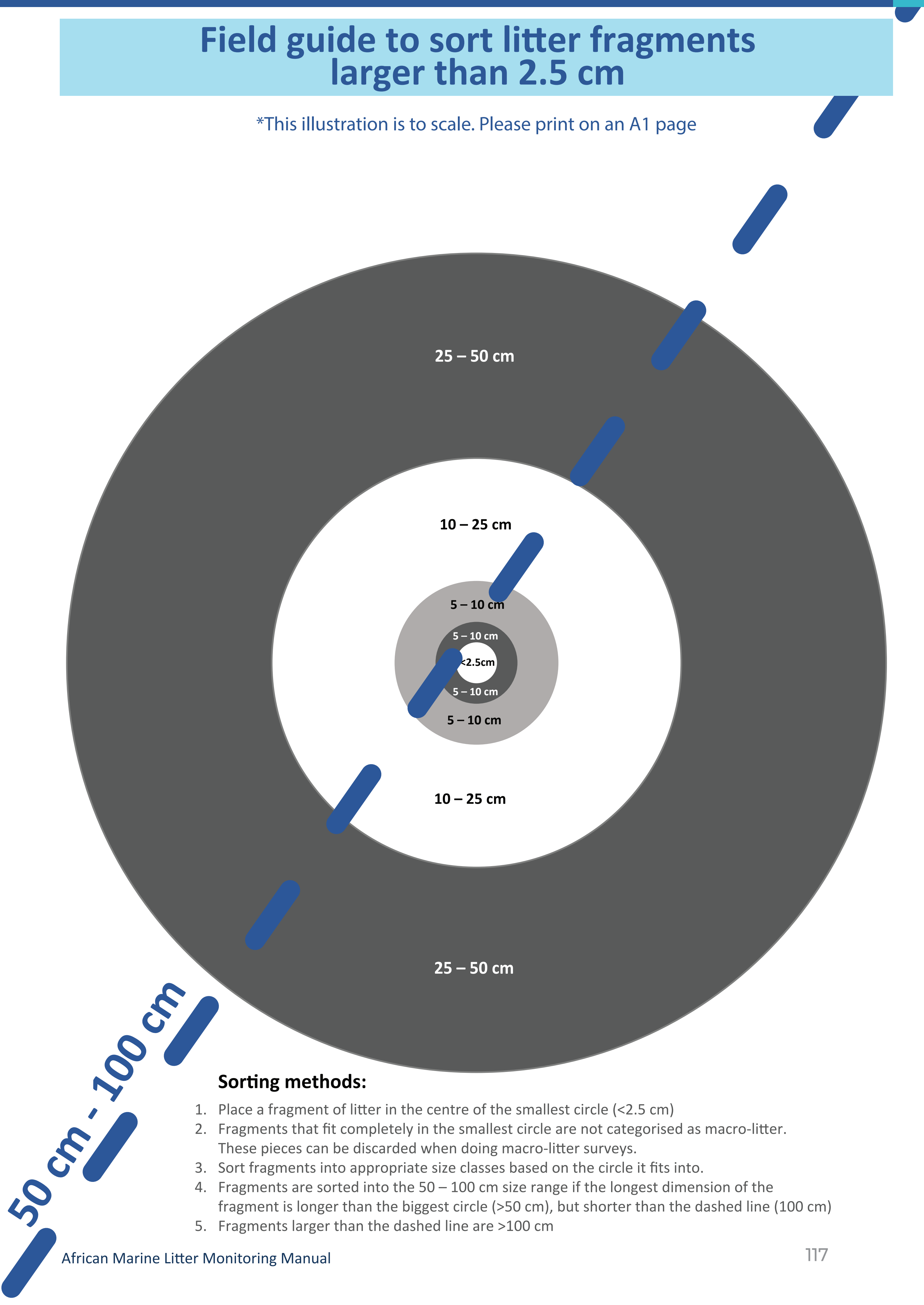
Construction Material & Pottery


Construction Material

Appendix 4

Field guide to sort litter fragments larger than 2.5 cm

*This illustration is to scale. Please print on an A1 page



Sorting methods:

1. Place a fragment of litter in the centre of the smallest circle (<2.5 cm)
2. Fragments that fit completely in the smallest circle are not categorised as macro-litter. These pieces can be discarded when doing macro-litter surveys.
3. Sort fragments into appropriate size classes based on the circle it fits into.
4. Fragments are sorted into the 50 – 100 cm size range if the longest dimension of the fragment is longer than the biggest circle (>50 cm), but shorter than the dashed line (100 cm)
5. Fragments larger than the dashed line are >100 cm

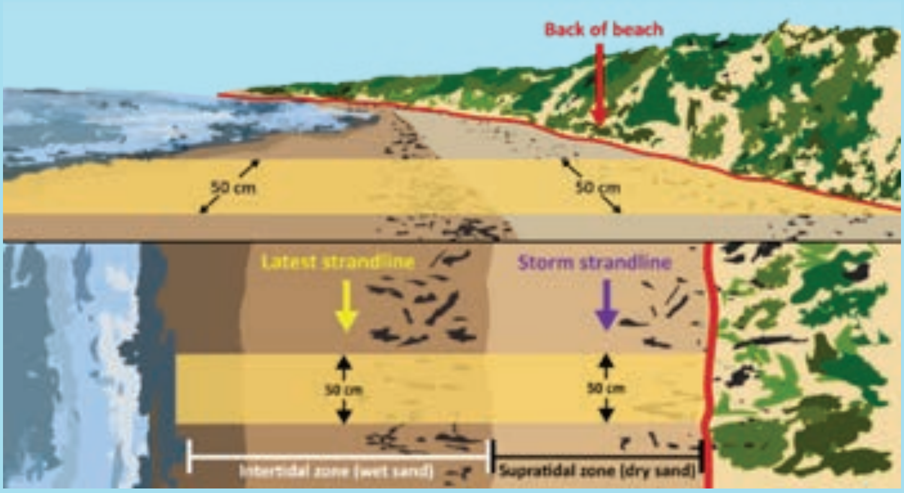
Appendix 5

FIELD GUIDE FOR MESO-LITTER SURVEYS ALONG SHORELINES

White boxes may be used to tick which steps have been completed

STEP 1: FIND A STUDY SITE

To include different strandlines, meso-litter sampling should be conducted along a 50 cm-wide strip transect from the edge of the water, to above the storm strandline (found towards the back of the beach). Only the dry sand of this transect will be sieved to collect buried litter (see **Step 2**). The study site description (**Datasheet 1**) needs to be completed before commencing with litter collection.



STEP 2: COLLECT MESO-LITTER

1. Inspect the strip transect from the edge of the water to above the storm strandline and collect all visible litter at the surface of the sand.

2. From above the most recent strandline (found at the most recent high-water mark) to above the storm strandline, collect the upper 5 cm of sand using a hand spade.

3. Sieve the collected sand through stacked sieves with mesh sizes of 25 mm and 2 mm. Items >25 mm and <2 mm can be disposed of. Special care should be taken to collect litter items between 2 – 25 mm that may fall through the sieves e.g., long, thin fibres.

4. Remove rocks and biological material from the sieves and transfer the remaining material on the 2 mm sieve into containers or bags for processing in the laboratory.

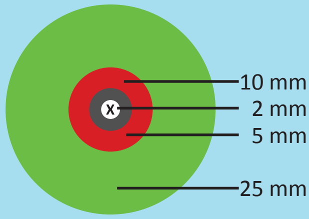
Appendix 5

STEP 3: SEPARATE LITTER FROM OTHER MATERIAL

Easily identifiable pieces of litter can be removed from the material collected in the field for further analysis. To minimize the risk of overlooking small plastic items, all remaining debris should be added to a 20 L bucket of seawater. Some plastics should float and can be collected from the top of the seawater. To collect the remaining high-density plastics, stir the water vigorously, and collect the floating plastics. The remaining material (e.g., sand, shells and seaweed) which do not qualify as litter should be discarded in an appropriate manner.

STEP 4: SEPARATE LITTER BY SIZE

Litter should be separated by hand into different fragment size categories (i.e., 2–5 mm, 5–10 mm, and 10–25 mm). Grids of different sizes (**Appendix 6**) may be used to sort litter into the appropriate site categories.



STEP 5: PROCESS THE LITTER

After litter pieces have been separated by size, all litter pieces must be:

1. Cleaned to remove any remaining sand and/or biological material that may influence weight measurements.

2. Air-dried

3. Counted and categorized as per the meso-litter datasheet (**Datasheet 5**). See **Appendix** 7 for a visual guide of meso-litter categories.

4. Weighed per category (e.g., "Ropes/ Fibres") to the nearest 1 mg/ 0.001 g.

STEP 6: DISPOSE OF LITTER

Once the survey is complete, collected litter must be correctly disposed of or stored for further analysis.

MESO-LITTER SORTING GRID

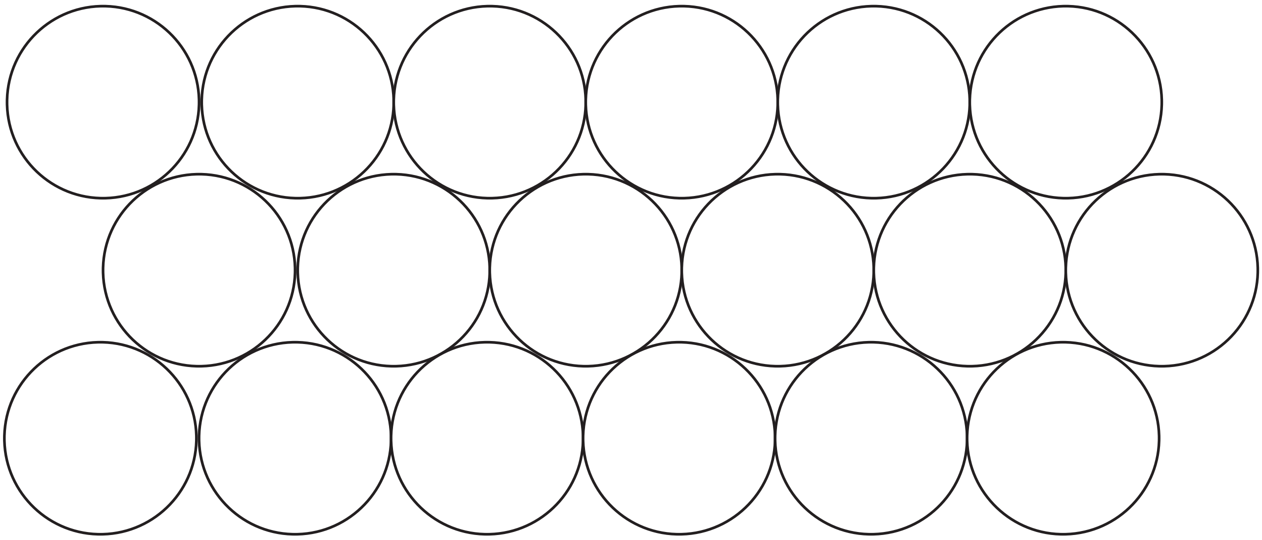
A field-guide to sort litter fragments between 2 mm & 25 mm

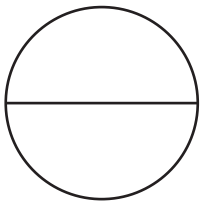
(*These illustrations are to scale. Please print on an A4 page)

10 – 25 MM ITEMS

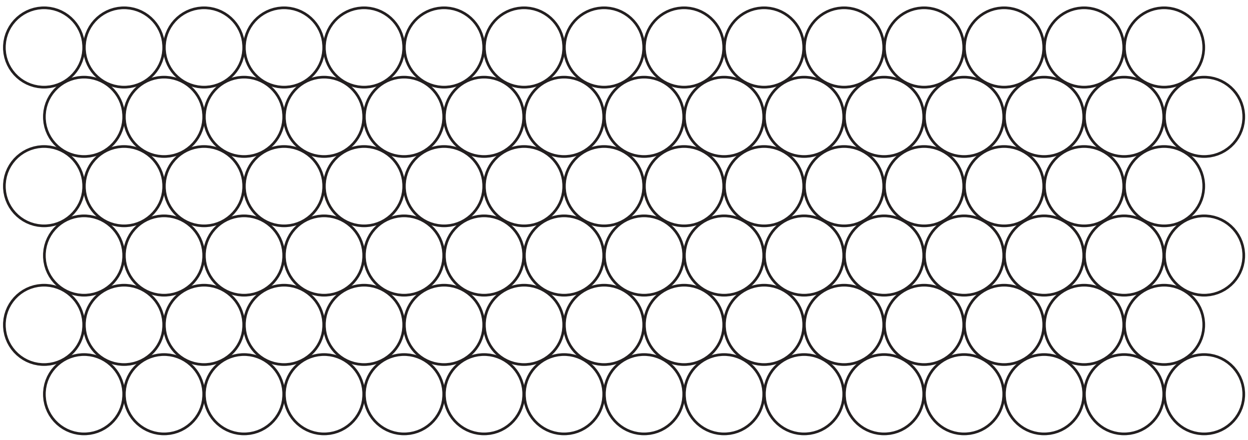
Sorting methods:

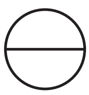
1. Items larger than the big circles (25 mm) should be discarded.
2. Items smaller than the big circles but larger than the smaller circles (10 mm) are sorted into the 10–25 mm size category.
3. Items smaller than the small circles should be measured on the next page (5–10 mm items).





25 mm



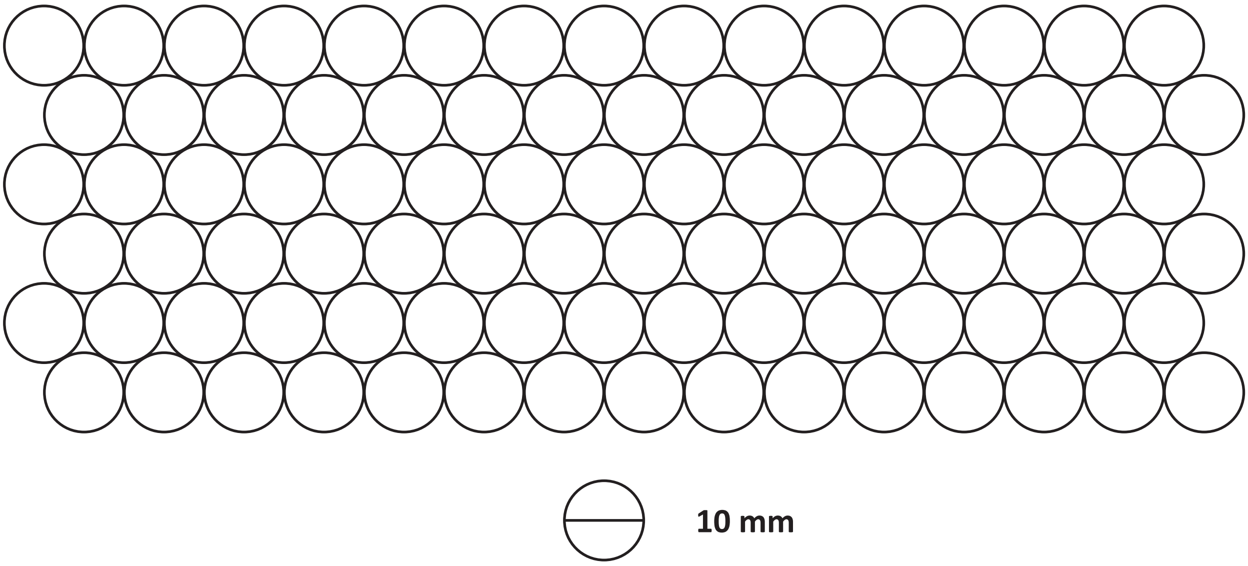


10 mm

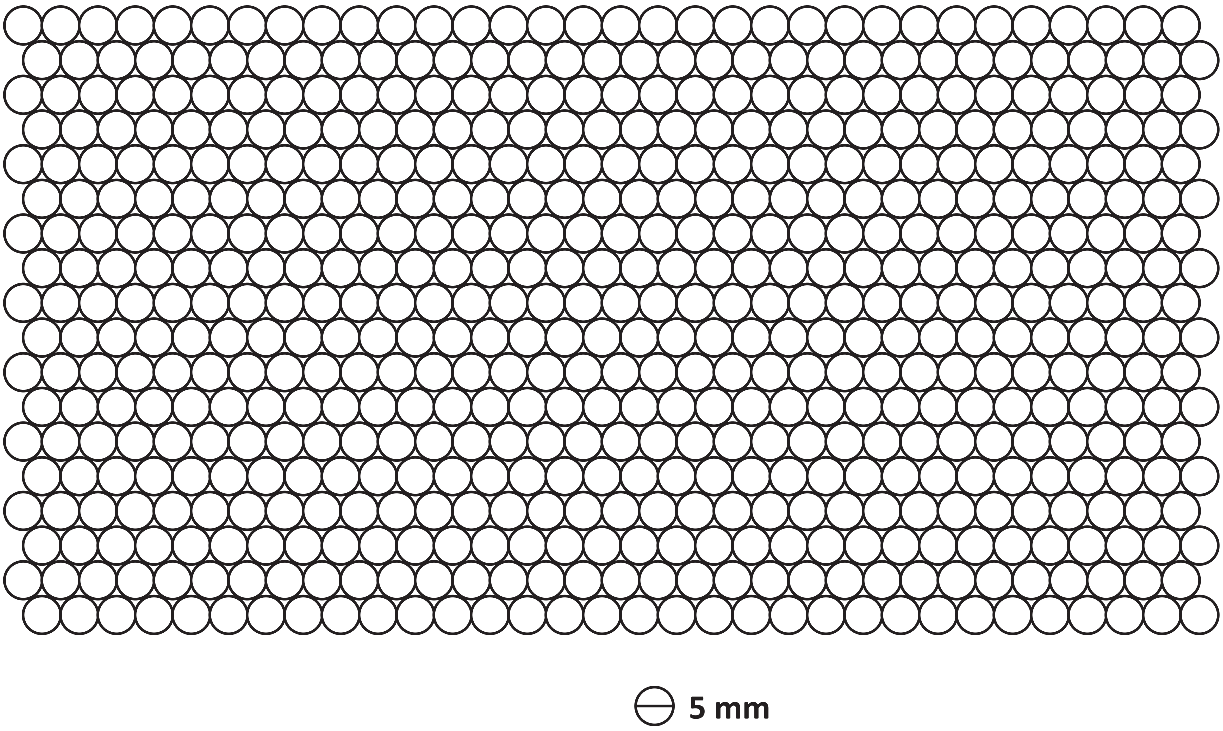
5 – 10 MM ITEMS

Sorting methods:

1. **Items larger than the big circles (10 mm) should be measured on the previous page (10–25 mm items).**
2. **Items smaller than the big circles but larger than the smaller circles (5 mm) are sorted into the 5–10 mm size category.**
3. **Items smaller than the small circles should be measured on the next page (2–5 mm items).**



10 mm

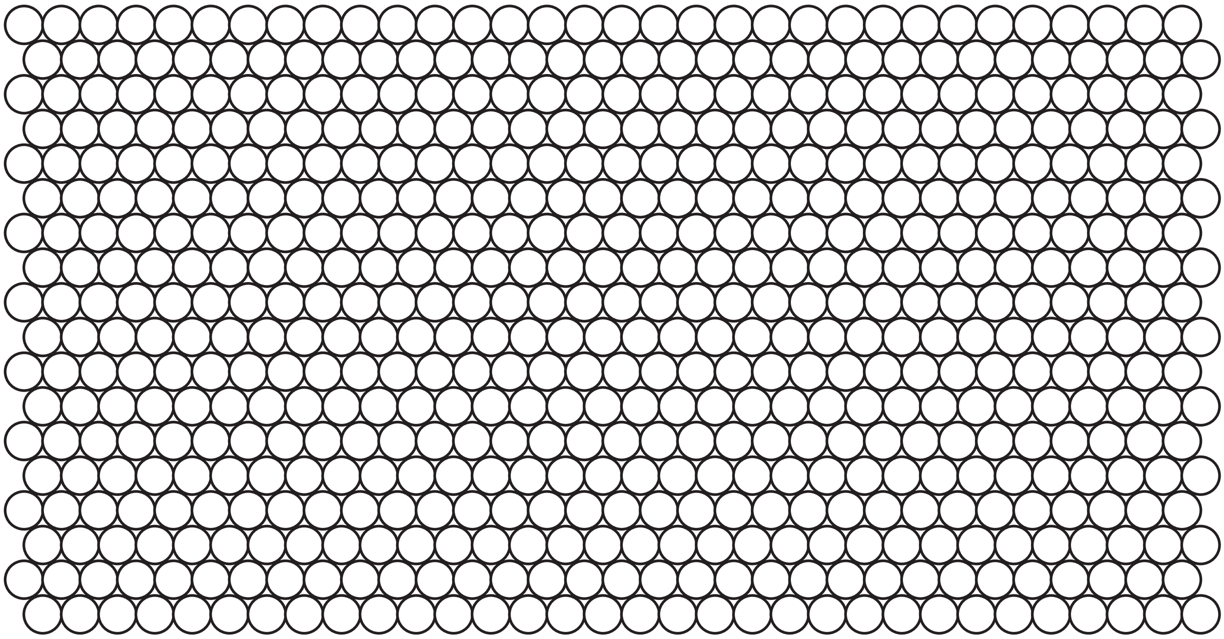


5 mm

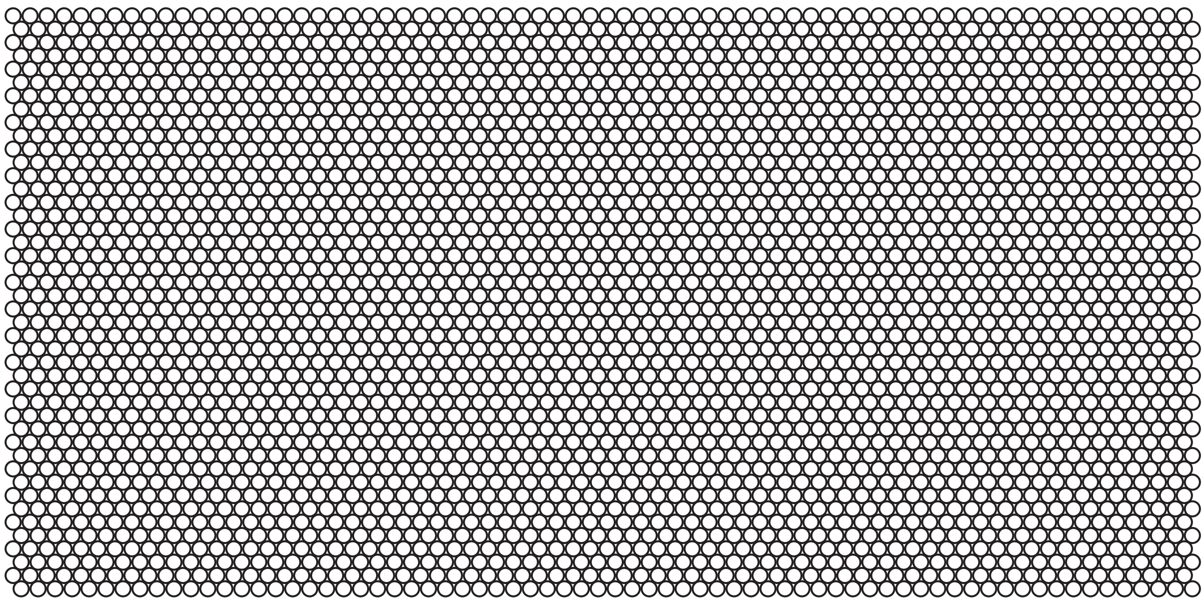
2 – 5 MM ITEMS

Sorting methods:

1. **Items larger than the big circles (5 mm) should be measured on the previous page (5–10 mm items).**
2. **Items smaller than the big circles but larger than the smaller circles (2 mm) are sorted into the 2–5 mm size category.**
3. **Items smaller than the small circles should be discarded.**



5 mm

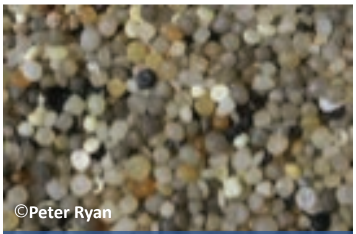


2 mm

Appendix 7

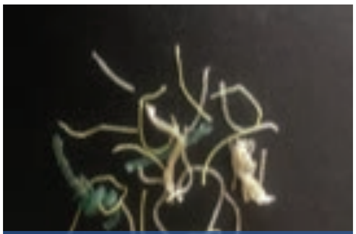
VISUAL GUIDE TO MESO-LITTER CLASSIFICATION

Plastic Objects



Industrial Pellets/Nurdles


Cigarette butts


Fishing Line


Flexible Packaging


Foamed Plastics


Bottle Caps/Lids/Lid Rings


Rigid Pieces


Ropes/ Fibres

Non-Plastic Objects


Construction Material & Ceramics


Fabric/Cloth


Glass


Metal


Paper/Cardboard


Processed Wood/Cork


Rubber/Silicon

Appendix 8

FIELD GUIDE FOR MACRO-LITTER ACCUMULATION SURVEYS IN MANGROVES

White boxes may be used to tick which steps have been completed

STEP 1: FIND A STUDY SITE

1. Surveys are conducted within squares/quadrats running parallel to the shoreline, within three inundation zones (landward, middle, and seaward zones).

2. Three transect lines (one per zone) 210 m in length and 60 m in width are set parallel to the shoreline and spaced 15 m apart. Quadrats in the seaward zone should be set up first at the low water mark each day.

3. GPS coordinates should be taken at the centre of the quadrats to revisit the same location each day of the survey.

4. Each transect is divided into 15 10x10 m quadrats with 5 m between each quadrat (totaling 45 quadrats per 210 m site). Quadrats should be demarcated using a rope to connect four PVC poles.

STEP 2: DESCRIBE THE SITE

Study site information should be recorded (**Datasheet 1**). This datasheet should only be completed once per survey (on Day Zero). Daily changes in site conditions (e.g., weather and wind speeds) need to be recorded on **Datasheet 2** every time the site is surveyed.

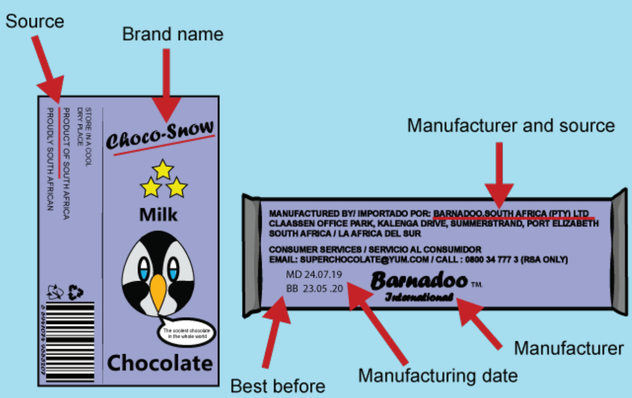
STEP 3: CLEAN UP THE SITE

An initial Day Zero clean-up of the study site is needed before accumulation surveys. These data from Day Zero will not be incorporated into the accumulation study. All visible macro-litter should be removed.

STEP 4: DO A BRAND AUDIT

It is recommended to perform a brand audit on the litter collected during the initial Day Zero clean-up of the study site. Information regarding the brand name, manufacturer, source of the litter (local or foreign), type of product, type of packaging, and date manufactured or best before (BB) dates (when date manufactured is not available) are required for each piece of branded litter.

A brand audit datasheet (**Datasheet 3**) is provided, and a visual guide (**Appendix 2**) is available to aid in the brand auditing process.



STEP 5: DO A DAILY SURVEY OF THE STUDY SITE

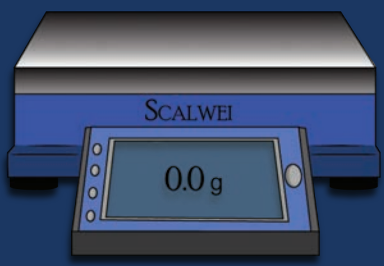
1. Quadrats cleaned on Day Zero will be surveyed at low tide on Day 1, Day 5 and Day 9, starting the day after the Day Zero/standing-stock clean-up, to collect any accumulated litter. Re-usable collection bags/containers should be clearly labelled to include the study site name, date of collection, zone of collection (i.e., seaward, middle, or landward zone), and quadrat number.

2. If an item of litter is too large to be removed (e.g., tractor tyres or buried ropes/nets), make a clear, recognizable mark (e.g., using paint) to prevent being counted again.

3. Potentially dangerous items such as chemicals, weapons, and ammunition should be recorded and counted but not handled

STEP 6: WORK IN THE LAB

Clean and dry each piece of litter before weighing. Be sure to remove all soil from the litter items. Every piece of macro-litter needs to be categorized into litter types as per **Datasheet 4** (which should be completed daily for each quadrat), and then counted and weighed per litter type (e.g., earbuds) to the nearest 0.1 g or 1 kg for larger items. **Appendix 4** may be used to sort litter fragments into different size classes. Separate datasheets should also be used for each day of the survey.



STEP 7: REPEAT STEPS 5 & 6

For accumulation surveys, repeat the survey on Day 1, Day 5 and Day 9, within the exact same quadrats as for the initial Day Zero clean-up. New datasheets for site conditions and litter need to be completed for each day of the survey.

Appendix 9

FIELD GUIDE FOR MESO-LITTER ACCUMULATION SURVEYS IN MANGROVES

White boxes may be used to tick which steps have been completed

STEP 1: SET UP STUDY SITE

1. Surveys are conducted within squares/quadrats running parallel to the shoreline, within three tidal inundation zones (landward, middle, and seaward zones).
2. Three transect lines (one per zone) 84.5 m in length and 31.5 m in width are set parallel to the shoreline and spaced 15 m apart. Quadrats in the seaward zone should be set up first at the low water mark each day.
3. GPS coordinates should be taken at the centre of the quadrats to revisit the same location each day of the survey.
4. Each transect is divided into nine 50 x 50 cm quadrats with 10 m between each quadrat (totalling 27 quadrats per 84.5 m site). Quadrats can be demarcated using small flags, or PVC squares of appropriate size.
5. If site width is <31.5 m, only two transects (one seaward and one other) can be used and spaced 15 m apart. If site length is <84.5 m, space between transects can be reduced to 5–15 m. Quadrats must remain 50 x 50 cm.

STEP 2: DESCRIBE THE SITE

Study site information should be recorded (**Datasheet 1**). This datasheet should only be completed once per survey (on Day Zero). Daily changes in site conditions (e.g., weather and wind speeds) need to be recorded on **Datasheet 2** every time the site is surveyed.

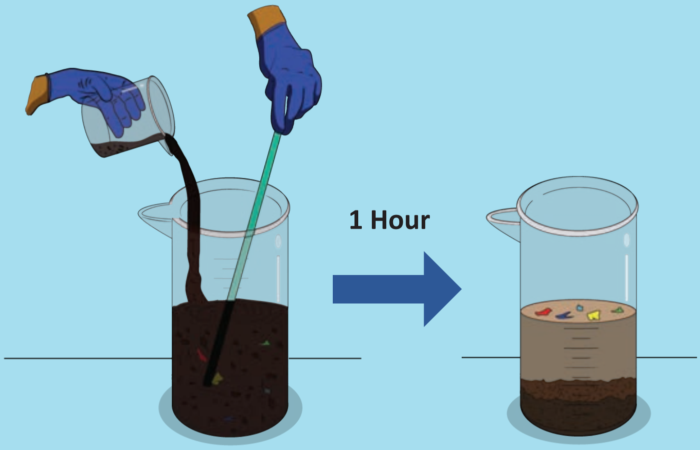
STEP 3: SAMPLE COLLECTION

1. Within each quadrat, the top 3 cm of sediment is collected using a hand spade and put in a reusable bag/container. A ruler can be used to ensure that the top 3 cm of sediment is collected. Collection bags/containers should be labelled to include the study site name, date, zone of collection (i.e., seaward, middle, or landward zone), and quadrat number.
2. One sediment sample should be collected from each of the nine quadrats.

Appendix 9

STEP 4: SEPARATING LITTER FROM SEDIMENT

1. The sediment sample collected from each quadrat should be air-dried and 1 kg is randomly selected from each.
2. The 1 kg of sediment is added to a glass beaker containing a salt solution and stirred vigorously for five minutes with a stirrer. The solution is then left to stand for an hour, allowing floatation of meso-litter.

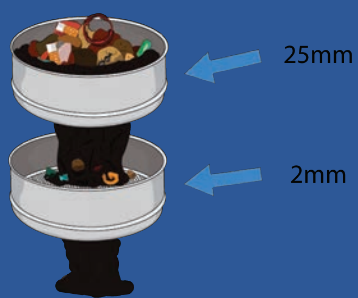


STEP 5: COLLECT FLOATING LITTER

1. The supernatant (the watery mixture above the sediment) is poured through stacked sieves (mesh sizes of 11 mm, 10 mm, 5 mm, 4 mm, 2 mm) allowing meso-litter particle separation by size.
2. Litter should be sorted into fragment size categories as per **Datasheet 5** based on longest dimension.
3. Separation and sieving are repeated once, using the remaining sediment that settled in the beaker to maximize recovery of meso-litter samples.

STEP 6: COLLECT REMAINING LITTER

Following second separation, sieves are washed with freshwater to separate any remaining meso-litter from sediment. Meso-litter retained on the sieves can be added to the previous litter of the same size.



STEP 7: PROCESS THE LITTER

1. All collected litter pieces must be cleaned to remove biological material, air-dried, counted, and categorized according to **Datasheet 5**.

2. All Items must be weighed per category to the nearest 1 mg/ 0.001 g.

STEP 8: DISPOSE OF LITTER

Once the survey is completed and all the meso-litter items have been weighed and categorized by size, collected litter must be correctly disposed of or stored for further analysis

Appendix 10

FIELD GUIDE FOR LITTER SURVEYS IN RIVERS AND ESTUARIES

White boxes may be used to tick which steps have been completed

STEP 1: FIND A STUDY SITE

1. Surveys are conducted from bridges or anchored boats in rivers or estuaries using a specially designed 2 x 1 m net (called the STOP net) with a mesh size of 2 mm.

2. Surveys should be conducted during rainfall/ high-flow conditions as well as low-flow conditions.

3. Surveys should be conducted in the area of the river with strongest flow. This area usually contains the most litter. In estuaries, sampling should be conducted when the river is flowing at its strongest (±3 hours after high tide).

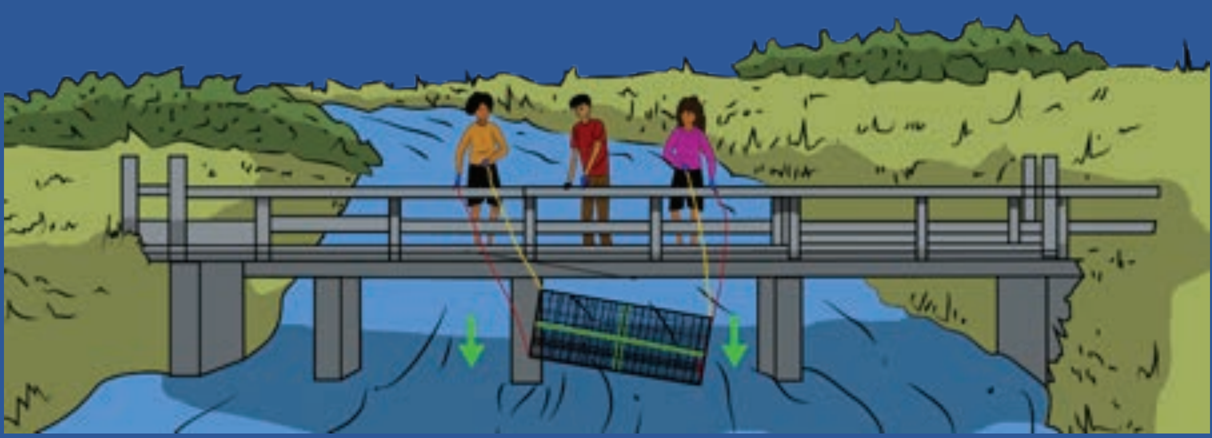
4. The STOP net should only be used in winds <20 km/h.

STEP 2: DESCRIBE THE SITE

Study-site descriptions (**Datasheet 6**) and site conditions (**Datasheet 7**) need to be measured and recorded before commencing with any clean-ups or surveying. **Datasheet 6** will only need to be completed once during the duration of the survey, but **Datasheet 7** will have to be completed daily before commencing with fieldwork.

STEP 3: NET DEPLOYMENT

Deploy the net as per instructions under Net deployment **Section 7.4.3** in **Chapter 7**.



STEP 4: SAMPLE COLLECTION

1. After 30 min of deployment time, retrieve the net via the STOP recovery method under **section 7.4.4** in **Chapter 7**.

2. Open the net on a tarpaulin/canvas and collect all visible litter and place in clearly labelled bags. Discard all non-litter items.

3. Deconstruct the net and tidy up the area. Dismantling the net is simply a reversal of the construction process.

STEP 5: LABORATORY ANALYSIS

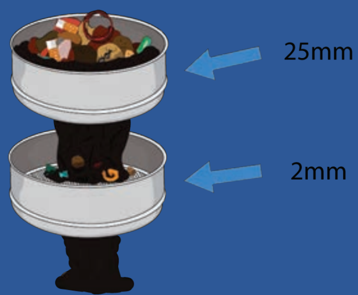
Macro-litter:

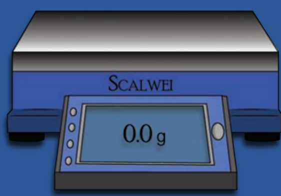
1. After removing all visible non-litter items, sieve the remaining material through stacked sieves with 25 mm and 2 mm mesh sizes.

2. Macro-litter on top of the sieve with the 25 mm mesh size should be washed to remove all biological material and then dried.

3. Count and categorize items into litter types as per **Datasheet 4**. See **Appendix 3** for a visual guide of categories. **Appendix 4** may be used to sort litter fragments into different size classes.

4. Weigh litter to the nearest 0.1 g.





Appendix 10

STEP 5: LABORATORY ANALYSIS

Meso-litter:

1. Litter remaining on the sieve with the 2 mm mesh size is categorized as meso-litter. Collect all visible litter for further processing.

2. The remaining material (i.e., litter and other material) should be added to a 20 L bucket of seawater and stirred until the material floats. Collect the floating litter (along with any litter at the bottom of the bucket) for further analysis.

3. Wash and dry litter.

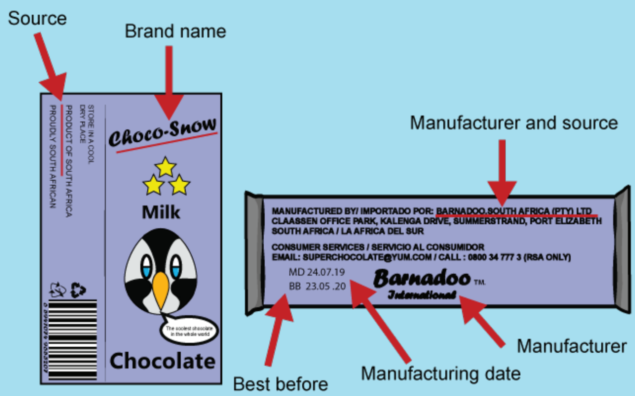
4. Count and categorize items into litter types as per **Datasheet 5**. **Appendix 6** may be used to sort litter fragments into different size classes.

5. Weigh litter to the nearest 0.001 g.

STEP 6: DO A BRAND AUDIT

It is recommended to perform a brand audit on the litter collected during the daily surveys. Information regarding the brand name, manufacturer, source of the litter (local or foreign), type of product, type of packaging, and date manufactured or best before (BB) dates (when date manufactured is not available) are required for each piece of branded litter.

A brand audit datasheet (**Datasheet 3**) is provided, and a visual guide (**Appendix 2**) is available to aid in the brand auditing process.



STEP 7: Discard Litter and Repeat

1. Once the survey is completed and all the litter items have been weighed and categorized by size, collected litter must be correctly disposed of or stored for further analysis.

2. Repeat steps 2–6 for 10 consecutive days.

FIELD GUIDE FOR MACRO-LITTER ACCUMULATION SURVEYS ON LAND

White boxes may be used to tick which steps have been completed

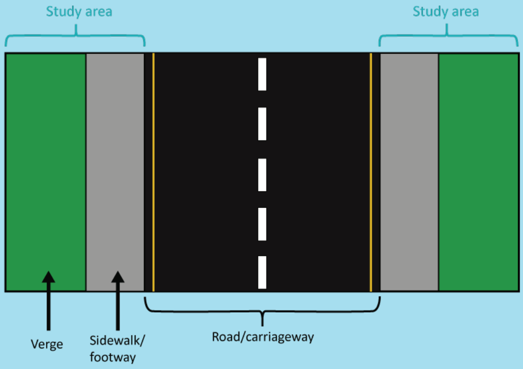
STEP 1: FIND A STUDY SITE


School yard


Parking lot


Public park


Taxi rank



Litter surveys on land may be conducted at any location where litter may accumulate but site selection will be guided by the research question. Potential sites include non-linear (e.g., school yards, public parks,) and linear (e.g., road verges) habitats. The exact area to be surveyed should be decided at the discretion of the surveyors and will depend on the research question. Signs should be erected within the study site to indicate that the study area should not be cleaned by third parties for the duration of the survey.

STEP 2: DESCRIBE THE SITE

Study-site descriptions (**Datasheet 8**) and site conditions (**Datasheet 2**) need to be measured and recorded before commencing with any clean-ups or surveying. **Datasheet 8** will only need to be completed once during the duration of the accumulation survey, but **Datasheet 2** will have to be completed daily before commencing with fieldwork

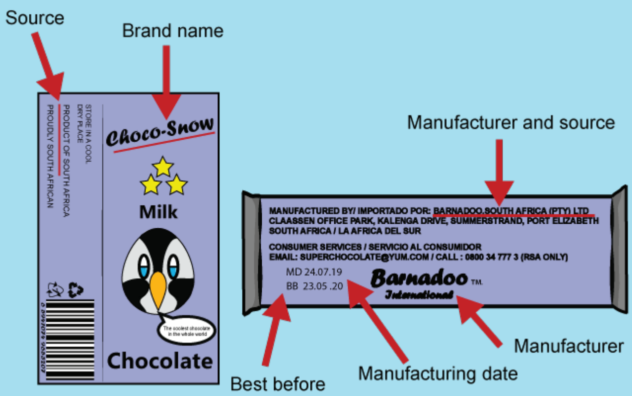
STEP 3: CLEAN UP THE SITE

An initial Day Zero clean-up of the study site is needed before accumulation surveys. These data from Day Zero will not be incorporated into the accumulation study. All visible macro-litter should be removed.

STEP 4: DO A BRAND AUDIT

It is recommended to perform a brand audit on the litter collected during the initial Day Zero clean-up of the study site. Information regarding the brand name, manufacturer, source of the litter (local or foreign), type of product, type of packaging, and date manufactured or best before (BB) dates (when date manufactured is not available) are required for each piece of branded litter.

A brand audit datasheet (**Datasheet 3**) is provided, and a visual guide (**Appendix 2**) is available to aid in the brand auditing process.



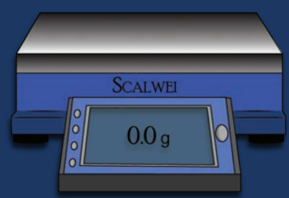
Appendix 11

STEP 5: DO A DAILY SURVEY OF THE STUDY SITE

After the initial Day Zero clean-up, the study site should be revisited daily for 7 consecutive days to collect all accumulated litter. Every piece of visible litter should be collected for analysis in the laboratory. Items that are too large or dangerous to remove should be recorded but not handled (see **Chapter 8** for details). Large items can be marked with paint to ensure that they are not counted in subsequent surveys.

STEP 6: WORK IN THE LAB

Clean and dry each piece of litter before weighing. Be sure to remove all soil from the litter items. Every piece of macro-litter needs to be categorized into litter types as per the macro-litter datasheet (**Datasheet 9**), and then counted and weighed per litter type (e.g., earbuds) to the nearest 0.1 g or 1 kg for larger items. **Appendix 3** provides a visual guide to litter classification. **Appendix 4** may be used to sort litter fragments into different size classes. Separate datasheets should also be used for each day of the survey.



STEP 9: REPEAT STEPS 5 & 6

For accumulation surveys, repeat the daily survey at the same study site for 7 consecutive days after the initial Day Zero clean-up. At the end of the study, the number of litter items and/or kg weight per 100 m per day will be calculated for linear habitats. In non-linear habitats, the number of litter items and/or kg weight will be calculated per square metre per day.

DATASHEET 1

<table>
<tr><th colspan="5">Datasheet 1: Site Description – Surveys along Shorelines
This datasheet should be completed once per survey</th></tr>
<tr><td>Organization</td><td></td><td>Date</td><td colspan="2">DD/MM/YYYY</td></tr>
<tr><td>Location Name</td><td></td><td>City, Province & Country</td><td colspan="2"></td></tr>
<tr><td>GPS Coordinates at start</td><td>Latitude
Longitude</td><td>GPS Coordinates at end</td><td colspan="2">Latitude
Longitude</td></tr>
<tr><td>Data recorder name</td><td colspan="4"></td></tr>
<tr><td colspan="5">Beach/Riverbank Characteristics</td></tr>
<tr><td>Habitat surveyed</td><td>Shoreline</td><td>Riverbank</td><td>Mangroves</td><td></td></tr>
<tr><td>Length of sampling transect</td><td colspan="2">m</td><td colspan="2"></td></tr>
<tr><td>Site width</td><td colspan="2">m</td><td colspan="2">From spring low mark to the back of the site. See manual for further instructions. Not applicable for mangroves</td></tr>
<tr><td>Horizontal tidal distance</td><td colspan="2">m</td><td colspan="2">Horizontal distance from spring low- to spring high-water mark</td></tr>
<tr><td>Dimensions of quadrats</td><td>Length m</td><td>Width m</td><td colspan="2">Only required for surveys in mangroves</td></tr>
<tr><td>Slope</td><td colspan="2"></td><td colspan="2">See manual for instructions</td></tr>
<tr><td rowspan="2">Substrate type</td><td>Sand | Mud</td><td>Pebble/gravel</td><td colspan="2" rowspan="2">Select the dominant substrate type</td></tr>
<tr><td>Boulders | Rock slab</td><td>Mangrove</td></tr>
<tr><td>Substrate uniformity</td><td colspan="2"></td><td colspan="2">% cover of main substrate type</td></tr>
<tr><td>Vertical tidal range</td><td>Min</td><td>Max</td><td colspan="2">Use a tide chart</td></tr>
<tr><td>Prevailing current</td><td colspan="2"></td><td colspan="2">Dominant current along coastline</td></tr>
<tr><td>Prevailing winds</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Aspect/orientation</td><td colspan="2"></td><td colspan="2">Direction faced when looking out at water</td></tr>
<tr><td rowspan="2">Back of the study site (the side facing away from the ocean/river)</td><td>Cliff | Seawall</td><td>Dune | Mangrove</td><td colspan="2" rowspan="2">Select one to describe back limit of the study site</td></tr>
<tr><td>Forest/ Trees (>3 m) | Shrub (<3 m)</td><td>Grass | Other:</td></tr>
<tr><td colspan="5">Land-use Characteristics</td></tr>
<tr><td rowspan="3">Location</td><td>Urban</td><td colspan="3">Often characterized by proximity to industrial zones and high population density.</td></tr>
<tr><td>Suburban</td><td colspan="3">Residential area outside or within a city; lower population density than urban areas</td></tr>
<tr><td>Rural</td><td colspan="3">Open areas lacking the extensive infrastructure of cities and towns; characterized by a low population density</td></tr>
</table>

DATASHEET 1

<table>
<tr><td>Major Land Usage</td><td>Fishing</td><td colspan="2">Sporting activities (e.g., swimming, surfing, walking etc.)</td><td>Sun-bathing</td><td colspan="2">Unutilized by the public/ restricted access</td><td>Other</td><td colspan="3">Select all options that apply</td></tr>
<tr><td>Number of visitors per day</td><td>0–100</td><td>101–1000</td><td>>1000</td><td colspan="3">Regularity of use</td><td colspan="2">Seasonal</td><td colspan="2">Year-round</td></tr>
<tr><td>Public access</td><td colspan="6"></td><td colspan="4">e.g., vehicular, pedestrian, boat or isolated</td></tr>
<tr><td>Nearest town</td><td colspan="3"></td><td colspan="2">Distance to town</td><td>km</td><td>Population size</td><td></td><td>Direction to town</td><td></td></tr>
<tr><td>Nearest river</td><td colspan="3"></td><td colspan="2">Distance to river</td><td colspan="2">km</td><td colspan="2">Direction to river</td><td></td></tr>
<tr><td>Nearest harbour/port</td><td colspan="3"></td><td colspan="2">Distance to harbour/ port</td><td>km</td><td>Type of harbour/ port</td><td></td><td>Direction to port</td><td></td></tr>
<tr><td>River input at beach</td><td>YES</td><td colspan="2">NO</td><td colspan="3">Pipe/drain input at beach</td><td colspan="2">YES</td><td colspan="2">NO</td></tr>
<tr><td>Notes</td><td colspan="6"></td><td colspan="4">Record any relevant information on, e.g., the environment, recent weather, anthropogenic activity, beach clean activity or special/ unusual observations and sightings</td></tr>
</table>

This datasheet has been adapted and modified from OSPAR Commission (2010) & Schuyler et al. (2018)

Datasheet 2: Site Conditions

This datasheet should be completed daily during a survey

Organization				**Date of survey**	DD/MM/YYYY		
Location name				**City, Province & Country**			
Data recorder name				**[1]Number of hours after previous high tide**			
Number of surveyors			**Start time**		**End time**		
Visibility	High	Medium	Low	**Time of most recent low tide**			
Current weather	Clear	Overcast	Drizzle / light rain	Heavy rain / storm	Fog/Mist		
Wind	N	S	E	*Wind at the time of survey. Select N/A if no wind*			
	NE	SE	W				
	NW	SW	N/A				
Wind speed	*km/h*						
Wind category	Calm	Light breeze (<10 km/h)	Moderate breeze (10–25 km/h)	Strong breeze (25–49 km/h)	High wind (50–65 km/h)	Gale (65–85 km/h)	
Evidence of dumping	None	Construction	Household	Other			
Notes				*Record any relevant information on, e.g., the environment, recent weather, anthropogenic activity, beach clean activity or special/ unusual observations and sightings*			

[1]*This field only needs to be completed if the study site is influenced by ocean tides. For example, a study site high up in a river will not be influenced by changes in tides lower down in the river.*

This datasheet has been adapted and modified from OSPAR Commission (2010) & Schuyler et al. (2018)

Datasheet 3: Brand Audit Form

Organization/Affiliation		**Date of audit**	DD/MM/YYYY-DD/MM/YYYY	**Number of volunteers**	
Location name		**City, Province/Region**		**Country**	
Name of data recorder		**Total volume collected** (# bags or containers)		**Volume of each bag or container**	
Site area	m^2	**GPS coordinates (start of transect)**		**GPS coordinates (end of transect)**	
Type of clean-up	Shoreline	Mangrove	River	Land	Other:

	Brand name	**Manufacturer/ parent company**	**Item description**	**Local/ foreign**	**Date of manufacturing**	**Best before (BB) date**	**Location of sale** (specify specific stores and their location)	**Type of product***	**Type of material****	**Layers***** (for plastic items only)	**Total pieces**
1											
2											
3											
∞											

*TYPE OF PRODUCT			
FP	**Food Packaging:** e.g. bottles, cans, cutlery, foam, tubs, wrappers, chip bags, cups, straws	**SM**	**Smoking Materials:** e.g. cigarette butts, lighters, cigar tips, tobacco packaging
PC	**Personal Care:** e.g. soap, shampoo, medical, diapers, makeup, dental, sanitary napkins	**FG**	**Fishing Gear:** e.g. nets, bait, lures, hooks, buoys, floats, rope, fishing lines, traps
HP	**Household Products:** e.g. cleansers, shoes, textiles, bags, toys, crates, tarps, pens	**PM**	**Packing Materials:** e.g. boxes, Styrofoam (non-food), film, bubble wrap, delivery envelopes, tape
O	**Other / Unknown:** e.g. pellets, balloons, metals, fragments & pieces, tires, zip ties, papers		

*****LAYERS**	**SL**	single layer, e.g. clear flexible plastic film, wrappers, polythene bags
	ML	multi-layer, e.g. composites, laminates, sachets, packets, "Tetra Pak"

**TYPE OF MATERIAL			
PET	#1 plastic: e.g. clear or tinted drink bottles, cups, or containers	**LDPE**	#4 plastic: e.g. trays, film, six-pack rings, snapon lids, wraps
HDPE	#2 plastic: e.g. hard & opaque bottles, milk jugs, polythene bags	**PP**	#5 plastic (polypropylene): e.g. food tubs, bottle caps & hinged lids, pill bottles
PVC	#3 plastic: e.g. pipes, shower curtains, toys	**PS**	#6 plastic (polystyrene): e.g. foam or hard plastic food containers, cups, lids
OP	Other plastics: e.g. #7 plastic, unknown or unidentifiable plastics	**CP**	Cardboard & Paper
G	Glass	**M**	Metal
O	Other material: Any other material not specified above, including rubber, fabric, wood, ceramics, other unknown or unidentifiable material		

This datasheet has been adapted with permission from the #BreakFreeFromPlastic brand audit datasheet.
Their official datasheet can be accessed at: https://www.breakfreefromplastic.org/ .

DATASHEET 4

Datasheet 4: Macro-litter Datasheet

This datasheet should be completed daily per survey. For surveys in mangroves, this datasheet should be completed daily for each quadrat.

Organization			**Data recorder name**	
Location of survey			**Date of survey**	DD/MM/YYYY
Ecosystem surveyed	Beach / Riverbank / Mangrove/ Other		**Start time**	
Type of survey	Accumulation survey	Standing-stock survey	**End time**	

FOR SHORELINE SURVEYS (e.g. beach, rocky shore, riverbank)**:**

Tidal zone sampled	Supratidal/ Dry sand	Intertidal/ Wet sand	**Distance surveyed**	*m*
GPS coordinates at start	Latitude Longitude		**GPS coordinates at end**	Latitude Longitude

FOR SURVEYS IN MANGROVES:

Inundation zone sampled	Seaward Zone	Middle Zone	Landward Zone	**GPS coordinates in middle of quadrat**	
Quadrat area	*m*^{2}			**Quadrat surveyed/code**	e.g., LWZ 3

FOR SURVEYS IN RIVERS AND ESTUARIES:

Type of survey	STOP net	Visual observations	**GPS coordinates**	

Litter Type	Count	Weight (g)	Litter Type	Count	Weight (g)
Paper & Cardboard Objects					
Cardboard			**Cups**		
Carton (e.g., tetrapak) **- Beverages**			**Paper** (e.g., newspaper)		
Carton - Food			**Paper Bags**		
Cigarette Packets			**Other** (specify under "Other Items" table below)		
Processed Wood Objects					
Cork			**Other Processed Wood Fragments** (10 – 25 cm)		
Ice Cream/Ice Lolly Sticks			**Other Processed Wood Fragments** (25 – 50 cm)		
Wooden Crates			**Other Processed Wood Fragments** (50 – 100 cm)		
Wooden Pallets			**Other Processed Wood Fragments** (>100 cm)		
Other Processed Wood Fragments (2.5 – 5 cm)			**Other** (specify under "Other Items" table below)		
Other Processed Wood Fragments (5 – 10 cm)					
Rubber Objects					
Balloons (including ribbons, strings, plastic valves)			**Rubber Fragments** (10 – 25 cm)		

Rubber Boots			**Rubber Fragments** (25 – 50 cm)		
Rubber Gloves			**Rubber Fragments** (50 – 100 cm)		
Tyres			**Rubber Fragments** (>100 cm)		
Rubber Fragments (2.5 – 5 cm)			**Other** (specify under "Other Items" table below)		
Rubber Fragments (5 – 10 cm)					
Clothing Objects					
Clothing			**Fabric fragments** (5 – 10 cm)		
Non-Rubber Gloves			**Fabric fragments** (10 – 25 cm)		
Shoes- Flip Flops			**Fabric fragments** (25 – 50 cm)		
Shoes- Other			**Fabric fragments** (50 – 100 cm)		
String (Cotton)			**Fabric fragments** (>100 cm)		
Fabric fragments (2.5 – 5 cm)			**Other** (specify under "Other Items" table below)		
Hygiene Objects					
Condoms			**Sanitary Pads/Panty Liners/Tampons/Tampon Applicators**		
Diapers			**Syringes/ Needles**		
Earbuds			**Wet Wipes/ Tissues/ Toilet Paper**		
Medical Containers/ Tubes			**Other** (specify under "Other Items" table below)		
Glass Objects					
Glass Bottle			**Glass Fragments** (25 – 50 cm)		
Light Bulb/ Tube			**Glass Fragments** (50 – 100 cm)		
Glass Fragments (2.5 –5 cm)			**Glass Fragments** (>100 cm)		
Glass Fragments (5 – 10 cm)			**Other** (specify under "Other Items" table below)		
Glass Fragments (10 – 25 cm)					
Plastic Objects					
Bags- Shopping			**Sellotape/ Duct Tape/ Plastic Stickers**		
Bags-Transparent (e.g., freezer bags)			**Strapping Bands**		
Bags- Woven (Polypropylene)			**Straws**		

Bags- Other			**Synthetic Hair**		
Bottles- Beverage			**Tarpaulin/ Sheeting**		
Bottles- Cleaning Products			**Toothbrushes/ Toothpaste Tubes**		
Bottles- Cosmetics/ Personal Care			**Toys**		
Bubble Wrap			**Utensils/ Cutlery**		
Buckets (not single-use)			**Wrappers/Packaging - Cleaning Products**		
Cable Ties			**Wrappers/Packaging – Cosmetics/ Personal Care**		
Caps/ Lids/ Lid Rings			**Wrappers/Packaging- Food/ Drink**		
Carpets/ Flooring			**Plastic Fragments - Film** (2.5 – 5 cm)		
Cigarette Lighters			**Plastic Fragments - Film** (5 – 10 cm)		
Cigarettes			**Plastic Fragments - Film** (10 – 25 cm)		
Containers/Tubs/Single-use Buckets - Cleaning Products			**Plastic Fragments - Film** (25 – 50 cm)		
Containers/Tubs/Single-use Buckets-Cosmetics/ Personal Care			**Plastic Fragments - Film** (50 – 100 cm)		
Containers/Tubs/Single-use Buckets - Food			**Plastic Fragments - Film** (>100 cm)		
Crates			**Plastic Fragments - Hard** (2.5 – 5 cm)		
Cups			**Plastic Fragments - Hard** (5 – 10 cm)		
Hairbrushes/ Combs			**Plastic Fragments - Hard** (10 – 25 cm)		
Jerry Cans (Square Plastic containers with handle)			**Plastic Fragments - Hard** (25 – 50 cm)		
Lollipop Sticks			**Plastic Fragments - Hard** (50 – 100 cm)		
Mesh (e.g., vegetable bags or nets)			**Plastic Fragments - Hard** (>100 cm)		
Pens/ Stationery			**Other** (specify under “Other Items” table below)		
Plates					
Foam Objects					
Food Containers & Cups			**Hard Foam Fragments** (e.g., Polystyrene): (2.5 – 5 cm)		

DATASHEET 4

Cushioning/ Packaging Foam			**Hard Foam Fragments** (e.g., Polystyrene): (5 – 10 cm)		
Soft Foam Fragments (e.g., Sponge): (2.5 – 5 cm)			**Hard Foam Fragments** (e.g., Polystyrene): (10 – 25 cm)		
Soft Foam Fragments (e.g., Sponge): (5 – 10 cm)			**Hard Foam Fragments** (e.g., Polystyrene): (25 – 50 cm)		
Soft Foam Fragments (e.g., Sponge): (10 – 25 cm)			**Hard Foam Fragments** (e.g., Polystyrene): (50 – 100 cm)		
Soft Foam Fragments (e.g., Sponge): (25 – 50 cm)			**Hard Foam Fragments** (e.g., Polystyrene): (>100 cm)		
Soft Foam Fragments (e.g., Sponge): (50 – 100 cm)			**Other** (specify under "Other Items" table below)		
Soft Foam Fragments (e.g., Sponge): (>100 cm)					
Marine & Fishing Gear					
Buoys/Floats			**Lures/Jigs/Other Plastics**		
Fishing Line			**Rope/String (Synthetic)**		
Fishing Net			**Sinker/ Hook/ Lure/ Other metals**		
Fishing Traps			**Other** (specify under "Other Items" table below)		
Glow/Light Stick					
Metal Objects					
Aerosol/ Spray Cans			**Metal Fragments** (2.5 – 5 cm)		
Aluminium/ Tin cans- Beverages			**Metal Fragments** (5 – 10 cm)		
Aluminium/ Tin cans- Food			**Metal Fragments** (10 – 25 cm)		
Foil			**Metal Fragments** (25 – 50 cm)		
Metal Bottle Caps			**Metal Fragments** (50 – 100 cm)		
Metal Wire/ Mesh			**Metal Fragments** (>100 cm)		
Oil Drums			**Other** (specify under "Other Items" table below)		
Construction Material and Ceramics					
Fragments (2.5 – 5 cm)			**Fragments** (50 – 100 cm)		
Fragments (5 – 10 cm)			**Fragments** (>100 cm)		
Fragments (10 – 25 cm)			**Other** (specify under "Other Items" table below)		
Fragments (25 – 50 cm)					

DATASHEET 4

Other Items					

Datasheet 5: Meso-litter Datasheet

This datasheet should be completed per strip transect for surveys along shorelines and per quadrat for surveys in mangroves. For surveys in rivers and estuaries, this datasheet should be completed daily for the duration of the survey.

Organization		**Name of data recorder**	
Location of survey		**Date of survey**	DD/MM/YYYY
Ecosystem surveyed	Beach / Riverbank / Mangrove/River/Other	**Start time**	
Transect length		**End time**	

FOR SHORELINE SURVEYS (e.g. beach, rocky shore, riverbank)**:**

GPS coordinates *(in middle of transect*:		**Sampled from most recent strandline to storm strandline**	Yes	No

FOR SURVEYS IN MANGROVES:

GPS coordinates *(in middle of the quadrat)*		**Quadrat surveyed/code**	e.g., LWZ 3

FOR SURVEYS IN RIVERS AND ESTUARIES:

GPS coordinates	

Litter Type	Fragment size	Count	Weight (g)
Plastic Objects			
Industrial Pellets/ Nurdles	*2 - 5 mm*		
Cigarette Butts	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Fishing Line	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Flexible Packaging	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Foamed Plastics	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Bottle Caps, Lids & Lid Rings	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Rigid Pieces	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Ropes/ Fibres	*2 - 5 mm*		
	5 - 10 mm		

	10 - 25 mm		
Non-Plastic Objects			
Construction Material & Ceramics	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Fabric/ Cloth	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Glass	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Metal	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Paper/ Cardboard	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Processed Wood/ Cork	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Rubber/ Silicon	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Wax	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		
Other	*2 - 5 mm*		
	5 - 10 mm		
	10 - 25 mm		

DATASHEET 6

Datasheet 6: Site Description – Surveys in Rivers and Estuaries

This datasheet should be completed once per survey.

Organization		**Date of survey**	DD/MM/YYYY
Location name		**City, Province & Country**	
GPS coordinates at bridge/access point	Latitude Longitude	**Habitat surveyed**	*River/estuary*
Data recorder name			

Water Body Characteristics

Presence of water	Permanent	Seasonal	Sporadic			
Connected to the ocean	YES	NO	**Distance from the ocean** (if connected to the ocean)			
Tidal influence	YES	NO	**Catchment area**		*km²*	*If available*
River width				*in m*	*Width at the site of sampling*	
Barrier at the edge of the water	*Rocks*	*Sediment*	*Grass*	*Shrubs (<3 m)*	*Select all options that apply within the observable study area*	
	Forest/ trees (>3 m)	*Marsh*	*Mangrove*	*Man-made structure*		

Land-use Characteristics

Location	Urban	*Often characterized by proximity to industrial zones and high population density.*
	Suburban	*Residential area outside or within a city; lower population density than urban areas*
	Rural	*Open areas lacking the extensive infrastructure of cities and towns; characterized by a low population density*

Major land usage	Agricultural	Commercial/ Municipal	Industrial	Natural/ Reserve	Residential	Roadway	*Select all options that apply*

Public access		*e.g., vehicular, pedestrian, boat or isolated*

Nearest town		**Distance to town**		**Population size**		**Direction to town**	

Pipe/drain input at site	YES	NO	

Notes		*Record any relevant information on, e.g., the environment, recent weather, anthropogenic activity, clean-up activity or special/ unusual observations and sightings*

DATASHEET 7

Datasheet 7: Site Conditions – Surveys in Rivers and Estuaries

This datasheet should be completed daily per survey.

Organization			**Date of survey**		DD/MM/YYYY		
Location name			**City, Province & Country**				
Data recorder name			**Start time**		**End time**		
Number of surveyors			**River width surveyed**		*For visual observations of floating litter*		
Current weather	Clear	Overcast	Drizzle/ light rain	Heavy rain/ storm	Fog/Mist		
Visibility	High	Medium	Low	[1]**Hours after last high-tide**			
Wind	N	S	E	*Wind at the time of survey. Select N/A if no wind*			
	NE	SE	W				
	NW	SW	N/A				
Wind speed	Calm	Light breeze (<10 km/h)	Moderate breeze (10-25 km/h)	Strong breeze (25-49 km/h)	High wind (50-65 km/h)	Gale (65-85 km/h)	
Evidence of dumping	None	Construction	Household	Other			
Height to water's surface	*in m*			*Measured from observer height on a bridge/boat.*			
Height to riverbed	*in m*			*Measured from observer height on a bridge/boat.*			
Water state				*e.g., calm, turbulent (natural foam present)*			
Water flow rate	*in* $m.s^{-1}$			*See manual for more information. Measured in metres per second.*			
Notes				*Record any relevant information on, e.g., the environment, recent weather, anthropogenic activity, beach clean activity or special/ unusual observations and sightings*			

Datasheet 8: Site Description – Surveys on Land

This datasheet should be completed once per survey.

Organization		**Date**	DD/MM/YYYY
Location Name		**City, Province & Country**	
GPS Coordinates at start	Latitude Longitude	**GPS Coordinates at end**	Latitude Longitude
Data recorder name			

Site Characteristics

Habitat surveyed	Linear habitat (i.e., street)		Non-linear habitat (e.g., school, parking lot, park)		Specify:	
Length of street	*in m*		**Both sides of the street surveyed**		YES	NO
Verge width sampled	*in m*		**Was the whole verge sampled**		YES	NO
Sidewalk/footway included	YES		NO		**Prevailing wind direction**	
Area of non-linear habitat	*in m^2*				Length x width	
Verge type/area terrain	Soil	Grass	Shrub (<3 m)	Forest/ Trees (>3 m)	*Select all that apply*	
	Concrete/ paving	Other:				
Barrier at the edge of the verge	Fence (<25 mm mesh size)	Fence (>25 mm mesh size)	Shrub (<3 m)	Forest/ Trees (>3 m)	*Select all that apply*	
	Concrete/ paving	Wall/ building	Other:			

Land-use Characteristics

Location	Urban	*Often characterized by proximity to industrial zones and high population density.*
	Suburban	*Residential area outside or within a city; lower population density than urban areas*
	Rural	*Open areas lacking the extensive infrastructure of cities and towns; characterized by a low population density*

Major Land Usage	Industrial	Commercial	Residential	Rural/Park	Informal settlement	Other:

Number of visitors per day	0-100	101-1000	>1000	**Regularity of use**	Seasonal	Year-round
Bins provided in study area	YES	NO		**Presence of stormwater drains/catch-pits**	YES	NO
Regular refuse collection	YES	NO		**Frequency of collection** (e.g., never, daily, weekly, bi-weekly, monthly)		
Notes					*Record any relevant information on, e.g., Festivals or anthropogenic activity, and other observations*	

Datasheet 9: Macro-litter Datasheet for Monitoring on Land

This datasheet should be completed daily per survey.

Organization			**Data recorder name**	
Habitat surveyed	Street/Parking lot, Public park etc.		**Location of survey**	
Type of survey	Accumulation Survey	Standing-Stock Survey	**Date of survey**	DD/MM/YYYY
Distance surveyed			**Start time**	
GPS coordinates at start	Latitude Longitude		**End time**	
GPS coordinates at end	Latitude Longitude			

Litter Type	Count	Weight (g)	Litter Type	Count	Weight (g)
Paper & Cardboard Objects					
Cardboard			**Cups**		
Carton (e.g., tetrapak) **- Beverages**			**Paper** (e.g., newspaper)		
Carton - Food			**Paper Bags**		
Cigarette Packets			**Other** (specify under "Other Items" table below)		
Processed Wood Objects					
Cork			**Other Processed Wood Fragments** (10 – 25 cm)		
Ice Cream/Ice Lolly Sticks			**Other Processed Wood Fragments** (25 – 50 cm)		
Wooden Crates			**Other Processed Wood Fragments** (50 – 100 cm)		
Wooden Pallets			**Other Processed Wood Fragments** (>100 cm)		
Other Processed Wood Fragments (2.5 – 5 cm)			**Other** (specify under "Other Items" table below)		
Other Processed Wood Fragments (5 – 10 cm)					
Rubber Objects					
Balloons (including ribbons, strings, plastic valves)			**Rubber Fragments** (10 – 25 cm)		
Rubber Boots			**Rubber Fragments** (25 – 50 cm)		
Rubber Gloves			**Rubber Fragments** (50 – 100 cm)		

Tyres			**Rubber Fragments** (>100 cm)		
Rubber Fragments (2.5 – 5 cm)			**Other** (specify under "Other Items" table below)		
Rubber Fragments (5 – 10 cm)					
Clothing Objects					
Clothing			**Fabric fragments** (5 – 10 cm)		
Non-Rubber Gloves			**Fabric fragments** (10 – 25 cm)		
Shoes- Flip Flops			**Fabric fragments** (25 – 50 cm)		
Shoes- Other			**Fabric fragments** (50 – 100 cm)		
String (Cotton)			**Fabric fragments** (>100 cm)		
Fabric fragments (2.5 – 5 cm)			**Other** (specify under "Other Items" table below)		
Hygiene Objects					
Condoms			**Sanitary Pads/Panty Liners/Tampons/Tampon Applicators**		
Diapers			**Syringes/ Needles**		
Earbuds			**Wet Wipes/ Tissues/ Toilet Paper**		
Medical Containers/ Tubes			**Other** (specify under "Other Items" table below)		
Glass Objects					
Glass Bottle			**Glass Fragments** (25 – 50 cm)		
Light Bulb/ Tube			**Glass Fragments** (50 – 100 cm)		
Glass Fragments (2.5 –5 cm)			**Glass Fragments** (>100 cm)		
Glass Fragments (5 – 10 cm)			**Other** (specify under "Other Items" table below)		
Glass Fragments (10 – 25 cm)					
Plastic Objects					
Bags- Shopping			**Sellotape/ Duct Tape/ Plastic Stickers**		
Bags-Transparent (e.g., freezer bags)			**Strapping Bands**		
Bags- Woven (Polypropylene)			**Straws**		

DATASHEET 9

Bags- Other			**Synthetic Hair**		
Bottles- Beverage			**Tarpaulin/ Sheeting**		
Bottles- Cleaning Products			**Toothbrushes/ Toothpaste Tubes**		
Bottles- Cosmetics/ Personal Care			**Toys**		
Bubble Wrap			**Utensils/ Cutlery**		
Buckets (not single-use)			**Wrappers/Packaging - Cleaning Products**		
Cable Ties			**Wrappers/Packaging – Cosmetics/ Personal Care**		
Caps/ Lids/ Lid Rings			**Wrappers/Packaging- Food/ Drink**		
Carpets/ Flooring			**Plastic Fragments - Film** (2.5 – 5 cm)		
Cigarette Lighters			**Plastic Fragments - Film** (5 – 10 cm)		
Cigarettes			**Plastic Fragments - Film** (10 – 25 cm)		
Containers/Tubs/Single-use Buckets - Cleaning Products			**Plastic Fragments - Film** (25 – 50 cm)		
Containers/Tubs/Single-use Buckets-Cosmetics/ Personal Care			**Plastic Fragments - Film** (50 – 100 cm)		
Containers/Tubs/Single-use Buckets - Food			**Plastic Fragments - Film** (>100 cm)		
Crates			**Plastic Fragments - Hard** (2.5 – 5 cm)		
Cups			**Plastic Fragments - Hard** (5 – 10 cm)		
Hair Brushes/ Combs			**Plastic Fragments - Hard** (10 – 25 cm)		
Jerry Cans (Square Plastic containers with handle)			**Plastic Fragments - Hard** (25 – 50 cm)		
Lollipop Sticks			**Plastic Fragments - Hard** (50 – 100 cm)		
Mesh (e.g., vegetable bags or nets)			**Plastic Fragments - Hard** (>100 cm)		
Pens/ Stationery			**Other** (specify under "Other Items" table below)		
Plates					
Foam Objects					
Food Containers & Cups			**Hard Foam Fragments** (e.g., Polystyrene): (2.5 – 5 cm)		

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Cushioning/ Packaging Foam			**Hard Foam Fragments** (e.g., Polystyrene): (5 – 10 cm)		
Soft Foam Fragments (e.g., Sponge): (2.5 – 5 cm)			**Hard Foam Fragments** (e.g., Polystyrene): (10 – 25 cm)		
Soft Foam Fragments (e.g., Sponge): (5 – 10 cm)			**Hard Foam Fragments** (e.g., Polystyrene): (25 – 50 cm)		
Soft Foam Fragments (e.g., Sponge): (10 – 25 cm)			**Hard Foam Fragments** (e.g., Polystyrene): (50 – 100 cm)		
Soft Foam Fragments (e.g., Sponge): (25 – 50 cm)			**Hard Foam Fragments** (e.g., Polystyrene): (>100 cm)		
Soft Foam Fragments (e.g., Sponge): (50 – 100 cm)			**Other** (specify under "Other Items" table below)		
Soft Foam Fragments (e.g., Sponge): (>100 cm)					
Metal Objects					
Aerosol/ Spray Cans			**Metal Fragments** (2.5 – 5 cm)		
Aluminium/ Tin cans- Beverages			**Metal Fragments** (5 – 10 cm)		
Aluminium/ Tin cans- Food			**Metal Fragments** (10 – 25 cm)		
Foil			**Metal Fragments** (25 – 50 cm)		
Metal Bottle Caps			**Metal Fragments** (50 – 100 cm)		
Metal Wire/ Mesh			**Metal Fragments** (>100 cm)		
Oil Drums			**Other** (specify under "Other Items" table below)		
Construction Material and Ceramics					
Fragments (2.5 – 5 cm)			**Fragments** (50 – 100 cm)		
Fragments (5 – 10 cm)			**Fragments** (>100 cm)		
Fragments (10 – 25 cm)			**Other** (specify under "Other Items" table below)		
Fragments (25 – 50 cm)					

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Other Items					