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5. MARINE SAMPLING FIELD MANUAL FOR BENTHIC STEREO BRUVS (BAITED REMOTE UNDERWATER VIDEO)

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5.1 Platform Description

Stereo-baited remote underwater video (stereo-BRUV) systems consist of two video cameras inside waterproof housings, attached to a base-bar and encased within a frame with some form of baited container in front of the cameras (Figure 5.1, Figure 5.2; Cappo et al. 2007). Benthic stereo-BRUVs are lowered to the seafloor and are left recording for a set duration. The video footage can then be used to assess the recorded fish assemblages and associated habitats. Stereo-BRUVs are becoming widely adopted as a non-extractive technique for sampling the relative abundance and size structure of fish assemblages (Cappo et al. 2004, 2007, Watson et al. 2009, Langlois et al. 2010, 2012, Hill et al. 2014, Whitmarsh et al. 2017).

5.1.1 Comparison of stereo-BRUV with other sampling methods

Importantly, baited video and stereo-BRUV have been found to be comparable to other commonly used ecological and fisheries dependent sampling methods. Willis et al. (2000) demonstrated that spatial variation in abundance estimates from baited video were comparable to variation in fisheries catch rates, and less confounded by behavioural biases potentially experienced by diver based visual methods (i.e. UVC). Subsequent studies have demonstrated that stereo-BRUVs overcome certain behavioural biases associated with Underwater Visual Census (UVC) techniques (Colton & Swearer 2010, Lowry et al. 2012), however UVC will typically record greater species diversity whereas baited video will record greater diversity and abundance of target species. Across latitudinal gradients, Langlois et al. (2010) demonstrated that measures of species richness/diversity obtained by baited video and diver based methods were comparable. Importantly for studies of the impacts of fishing pressure, biomass distribution and ecosystem dynamics, the size composition of targeted species sampled by stereo-BRUVs has been found to be comparable to line (Langlois et al. 2012) and trap (Langlois et al. 2015) fisheries.

5.1.2 Advantages of stereo-BRUV

As a non-extractive technique, stereo-BRUV have little impact on the ecosystem being studied, making this an ideal sampling platform to use in marine protected areas. The use of stereo-BRUVs also overcomes some of the biases associated with Underwater Visual Census (UVC) techniques (Colton & Swearer 2010, Lowry et al. 2012). Remote video eliminates the need for scuba diving, providing a strong safety advantage, while reducing the risk of incorrect fish identifications and inter-observer variability through recording a permanent and reviewable record. Furthermore, video techniques can access depths that are off-limits to divers and produce highly accurate length measurements (Harvey et al. 2001). The use of bait can increase the relative abundance and diversity of fishes observed, particularly species of interest to fisheries, without precluding the sampling of prey or herbivorous fish species (Lowry et al. 2012, Hardinge et al. 2013). Multiple stereo-BRUVs can be deployed in the field consecutively, making efficient use of researcher and boat time (Cappo et al. 2007, Langlois et al. 2010, Hill et al. 2014, Whitmarsh et al. 2017). This allows for the possibility of large spatial coverage and high replication even during short field campaigns.

5.1.3 Limitations of stereo-BRUV

The extent of the limitations and possible biases of stereo-BRUVs have been discussed in various studies (trophic biases, Goetze et al. 2015, bait biases, Langlois et al. 2015, behavioural biases, Coghlan et al. 2017). In addition, their suitability is decreased in habitats where the field of view is likely to be obscured (e.g. tall kelp habitats, very high relief reefs or low-visibility, highly turbid waters), similar to underwater visual censuses (UVCs). Nevertheless, BRUV technology is relatively simple and easy to deploy, providing consistent sampling of the benthic fish community and an index of abundance and diversity.

Overestimates of abundance can occur through double counting fish. This occurs when the same individual/s are viewed at different time points throughout a deployment. To overcome this, counts of the maximum number (MaxN) of individuals of any one species seen over the recording period have been used (Cappo et al. 2007, Harvey et al. 2007). In a monitoring context, comparative studies have suggested that the use of MaxN may be "hyper-stable" when fish abundance is high due to saturation of the field of view (Schobernd et al. 2013) and have suggested alternative metrics (e.g. MeanCount). However, MaxN is the most widely accepted metric in Australia and internationally, and provides an established option for standardisation between sampling programs.

In addition, the variation in the distance the bait plume travels, the responses of different fish species to the bait plume and the distances they will travel to get to the bait are unknown (Harvey et al. 2007). For these reasons, estimates of individual species abundance from BRUVs are currently limited to measures of relative abundance rather than density (Cappo et al. 2007). The use of MaxN also results in conservative estimates of the relative abundance and biomass of fish. Limitations have also been acknowledged for cryptobenthic and site-attached species that are often under-represented using video-based methods (Holmes et al. 2013). While BRUVs are considered unsuitable for estimating density, they are a powerful and cost-effective method for detecting spatial and temporal changes in the relative abundance and lengths of fish assemblages (Watson et al. 2009, Harvey et al. 2013, Hill et al. 2014, Malcolm et al. 2015).

Importantly, for sampling in deeper water habitats, the depth limitation of using roped stereo-BRUVs will depend on local conditions and will typically vary with water current conditions (e.g. ~1500 m, Zintzen et al. 2012). Non-roped stereo-BRUV systems have been developed internationally (Merritt et al. 2011) and in Australia (Marouchos et al. 2011) but have not yet been widely applied. In areas with strong currents, even in depths of ~60 m, the water resistance can act on the rope catenary to pull BRUV systems over, and the potential for this increases with depth. An associated limitation can include the surface floats being pulled underneath the surface until the current slows. Options for remotely deployed deepwater BRUVs using a sequence of bait release and monitoring over a 24-hour period, before the BRUV is released to the surface are still in development mode but have been trialled in the Flinders AMP (https://www.csiro.au/en/Research/OandA/Areas/Marine-technologies/Hi-tech-ocean-observing/DeepBRUVS).

5.1.4 Definition of terms

Sample

- Single observational unit (e.g. a single BRUV deployment).
- Sample/OpCode is interchangeable.

Method

- Sampling method, e.g. stereo-BRUV (stereo baited remote underwater video).

Campaign

- Discrete set (temporal and spatial) of Samples.
- Uses the same sampling and image analysis methods.
- CampaignID is a unique identifier for a Campaign made up of YYYY-MM_Project.name_Method (* is used to denote a CampaignID throughout this guide).

Project

- Contains one to multiple Campaigns with a shared purpose/objective (e.g. monitoring of a certain Marine Park, a bioregional study).
- Project is a unique identifier and the name should be carefully chosen (e.g. "MarineParkMonitoring" is not a good Project name but "Houtman Abrolhos Reef Observation Areas long-term monitoring" is a great Project name).

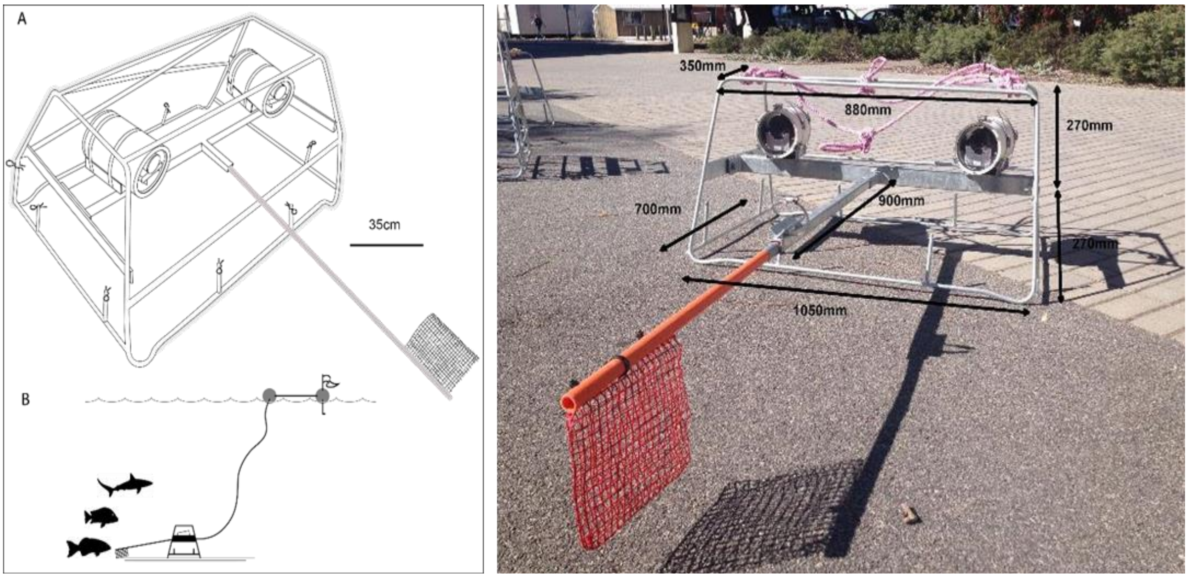

Figure 5.1 Left A: typical stereo baited remote underwater video (stereo-BRUV) and Left B: schematic of typical deployment setup of a stereo-BRUV unit sitting upright on the substrata with a rope leading to two buoys on the surface (Source: T. Simmonds/AIMS). Right: A photograph of a typical stereo-BRUV with the dimensions of the frame.

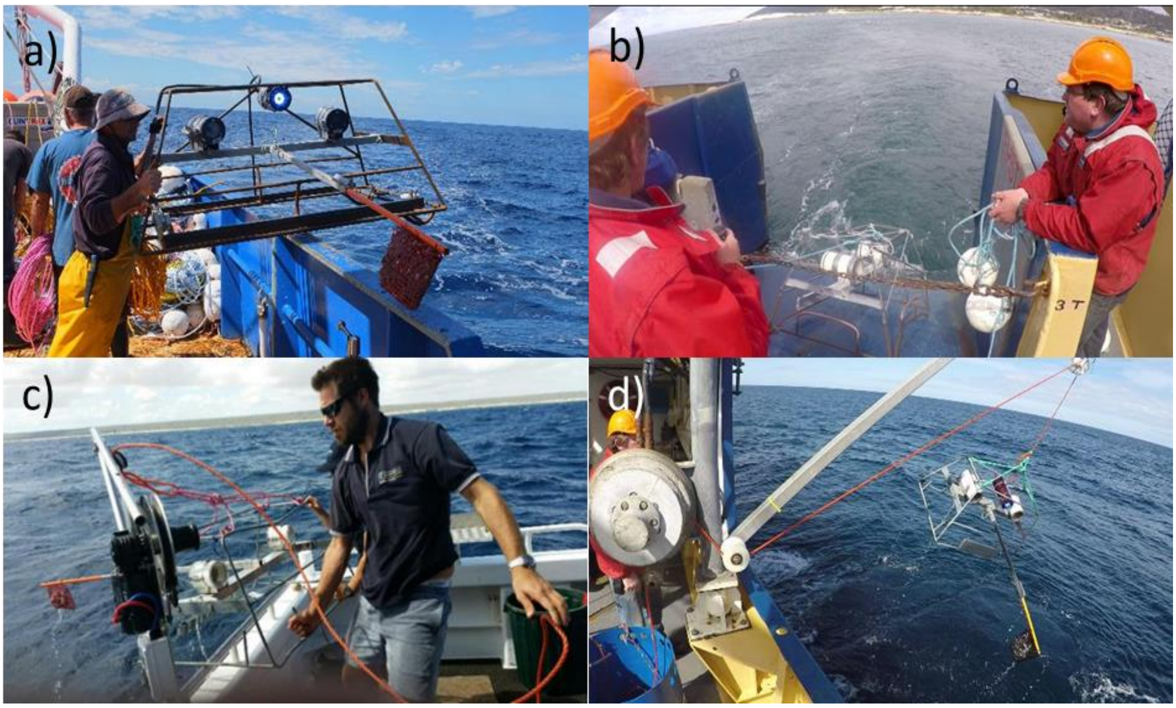

Figure 5.2 a) Deploying a stereo-BRUV from side of vessel. Note that this is a heavy-weight stereo-BRUV setup (Photo: C. Wellingtion/DPIRD). b) Deploying a stereo-BRUV through trawl door on a large vessel. c) Retrieving a standard stereo-BRUV. d) Retrieving a heavy-weight stereo-BRUV off large vessel.

5.2 Scope

This benthic stereo-BRUVs Field Manual includes gear designed to acquire imagery of demersal fish assemblages and their habitat within the field of view. A separate manual will address sampling pelagic fish assemblages using BRUVs (Chapter 6). This field manual covers everything required from equipment, pre-survey preparation, field procedures, post-survey procedures and data management for using benthic BRUVs to sample and monitor fish assemblages. The aim is to develop a consistent approach to using this field equipment and allow statistically sound comparisons between studies. Stereo-BRUVs are recommended, over mono-BRUVs, when monitoring demersal fish assemblages. Stereo-BRUVs consist of two cameras strategically and accurately placed on a frame that enable lengths and distance measurements to be made through the use of specialised software. These data are crucial to help monitor changes in fish assemblages over time. Therefore, the following standard operating procedures are written based on the use of stereo video.

5.3 Stereo-BRUVs in Marine Monitoring

A range of tethered and remote video methods, with roped and unroped designs, have historically been used to sample fish assemblages (see Mallet & Pelletier 2014). The use of BRUVs in scientific research has greatly increased over the past decade (Figure 5.3; Whitmarsh et al. 2017). This is in part due to the cost-efficiency and statistical power typically achieved for a wide range of trophic fish groups (Langlois et al. 2010) which has been recognised as an important metric for the investigation of ecosystem processes, the effects of fishing, and comparisons with fisheries-dependent data sets (Rochet & Trenkel 2003, Langlois et al. 2012). In Australia, benthic stereo-BRUVs have been used to successfully monitor spatial and temporal changes in benthic fish communities and their habitat structure (Figure 5.4; Cappo et al. 2004, Langlois et al. 2006, 2010, Harvey et al. 2013, Hill et al. 2014, Whitmarsh et al. 2017). There has been a steady increase in the use of stereo video over mono video systems, as equipment costs have fallen and the utility of length information for ecosystem studies has become apparent (Langlois et al. 2015). Stereo-BRUVs provide a non-extractive method for quantitatively assessing fish assemblages without the need for divers with the added benefit of having a permanent record if data are lost or identifications need to be checked. Many studies have compared the use of BRUVs with other 'traditional' methods such as diver transects, diver operated video (DOV), towed video or netting (Cappo et al. 2004, Watson et al. 2009, Colton & Swearer 2010, Langlois et al. 2010, Lowry et al. 2012, Goetze et al. 2015, Logan et al. 2017). In general, stereo-BRUVs recorded comparable species richness, greater abundance of targeted species with comparable size composition to fisheries dependent methos and provide the most cost effective method for sampling fish assemblages across a broad depth range (Langlois et al. 2010).

Sampling with stereo-BRUVs provides data for:

- Understanding anthropogenic impacts (fishing, climate change, oil and gas exploration, artificial reefs).
- Assessing changes in fish assemblage diversity, relative abundance, population size structure and growth.
- Exploring fish behaviour, including interactions between species.
- Determining the relationship between fish assemblages and their associated habitat structure.
- Assessing changes in fish assemblages and size structure across a depth gradient.

The following standard operating procedure provides a widely accepted protocol for the use of benthic stereo-BRUVs and will facilitate comparability of data from different surveys among space and time.

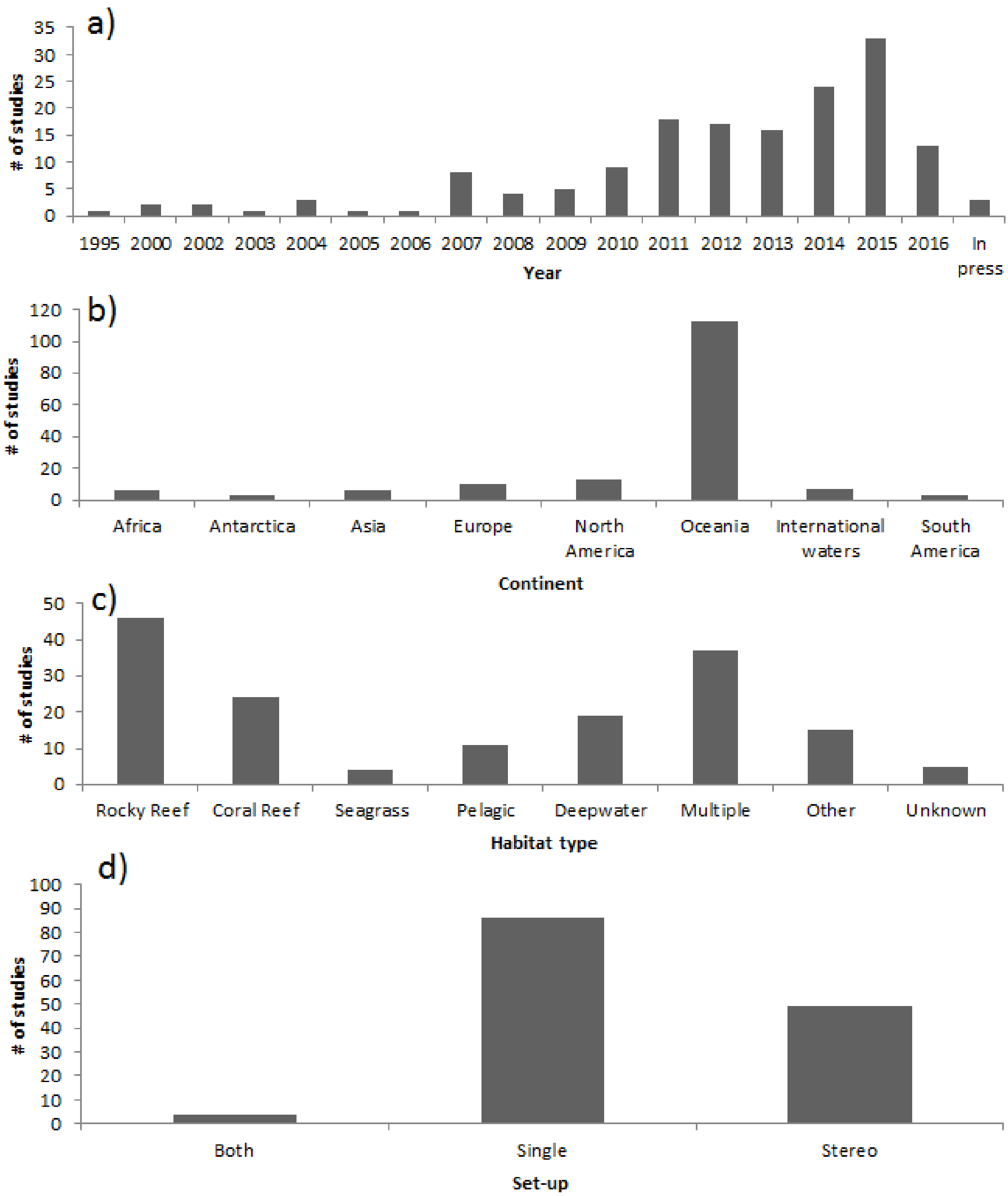

Figure 5.3 a) The The frequency of BRUVS studies published by year until 18/07/2016. b) The continent or geographical realm in which each study was conducted. c) The habitat type in which BRUVS were deployed for the 161 studies assessed. The 'Multiple' category was used where more than one habitat type was studied and included some of the other habitat categories listed (except for pelagic and deep-water), as well as some included in the 'Other' category, such as bare sand. 'Deep-water ([100 m)' habitats included shelf slope, soft sediments and hard substrates. d) The setup type used within each study, classified as either single (with one forward facing camera) or stereo (two cameras positioned to be able to determine fish measurements)(Source: Whitmarsh et al. 2017).

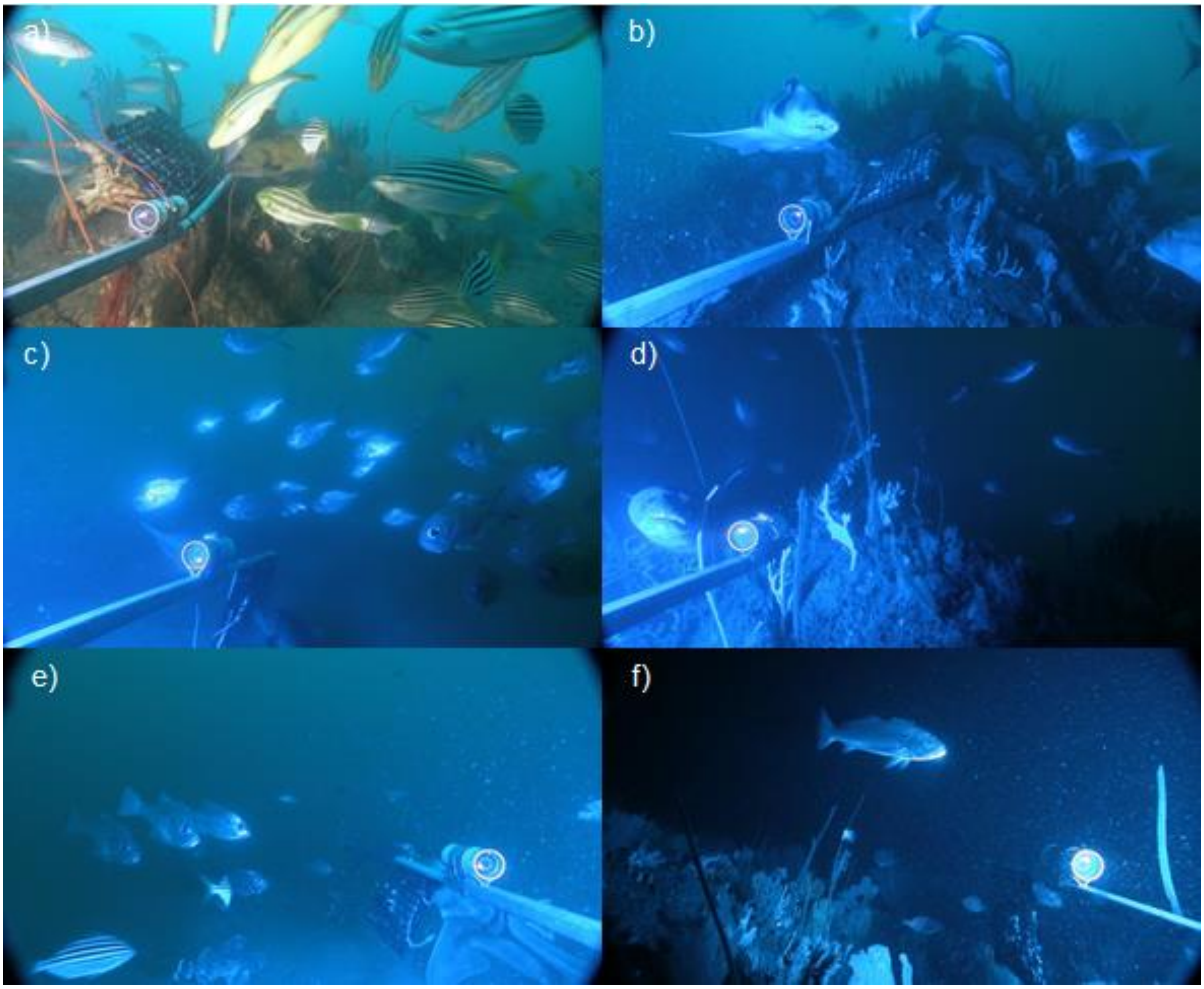

Figure 5.4 Examples of the fish assemblages observed using benthic stereo-BRUVs on reef and near reef sediments in 80-100 m of water in the Hunter CMR (Photos: J Williams NSW DPI). a) An example of mado (*Atypichthys strigatus*), ocean leatherjacket (*Nelusetta ayraudi*), and eastern rock lobster (*Sagmariasus verreauxi*). b) An example of Port Jackson shark (*Heterodontus portusjacksoni*) and silver sweep (*Scorpis lineolata*). c) An example of a school of nannygai (Centroberyx affinis) and an eastern wirrah (*Acanthistius ocellatus*). d) A conger eel (*Conger verreauxi*) and a school of nannygai (*Centroberyx affinis*). e) An example of a school of pearl perch (*Glaucosoma scapulare*), mado (*Atypichthys strigatus*), and Port Jackson shark (*Heterodontus portusjacksoni*). f) An example of a teraglin (*Atractoscion aequidens*).

5.4 Equipment

Equipment must be appropriately set up to ensure as much consistency as possible among surveys and facilitate gear replacement if necessary. The key components for a benthic stereo-BRUV include the following:

- Per stereo-BRUV unit:
    - 2 x cameras (with batteries and memory cards). Cameras capable of operating in low-light conditions are recommended (e.g. Canon HF G40 ~$1500). Cheaper action cameras (e.g. GoPro) are typically not adequate for low-light conditions.
    - 2 x camera housings (with o-rings)
    - Frame with weights
    - Bait arm with bait bag/container (reinforced if needed)
    - Bait
    - Synchronizing device (i.e. clapper board or synchronizing diode)
    - Lighting (If required, for example if sampling in depths >60m. Light colour choice is important and blue light is recommended (Fitzpatrick et al. 2013))
    - Additional weights (if sampling in high currents or at depths of >40 m)
    - Sensors (e.g. temperature, current profilers)
    - Spare parts kits (O-rings and silicone grease etc)
    - Spare cameras (note need to recalibrate if cameras are replaced, which can be done post survey)
    - Spare bait bags/bait arms
- Deployment / retrieval rig:
    - Rope (1.5:1 rope length to depth ratio)
    - Marker buoys
    - Winch (or pot hauler)
    - Protective gloves and helmet
    - Towel/Cloths
- Other
    - GPS
    - Site maps with coordinates of sites
    - Hard drives
    - Laptop(s) with charger(s)
    - Powerboards and extension leads
    - Data sheets
    - Permits
    - Spare batteries and memory cards
    - Grapnel, extra weight and rope for BRUV recovery

5.5 Pre-survey planning

<u>Confirm sampling design is statistically sound and feasible</u> with existing resources. Sampling design is crucial to ensuring that there is adequate replication and spatial independence to ensure a statistically sound study. Therefore, it is important that a statistician is consulted prior to beginning any sampling. Chapter 2 of this field manual package provides details of sampling design considerations, as well as example code and data for implementing a spatially-balanced design, as outlined in Foster et al. (2017). Specific sampling considerations pertaining to stereo-BRUVs include:

- Concurrent stereo-BRUVs should be separated by a minimum of 200-500 m to avoid bait plume overlap and animals moving between cameras.
- Deployments should be conducted at least 1 hour after sunrise and 1 hour before sunset to both improve visibility and remove the effect of crepuscular behaviour.
- Optimal soak time for comparisons with other studies is 60 mins. However, 30 min deployments may increase level of replication without sacrificing statistical power for reef-affiliated species accumulation curves (Harasti et al. 2015).

The time of fish biologists or taxonomists should be included as line items in budgets to ensure that all footage can meet appropriate QA/QC checks and species can be correctly identified. Care must be taken to ensure that a consistent nomenclature is used, with FishBase, the World Register of Marine Species (WoRMS) and the Codes for Australian Aquatic Biota (CAAB) being popular, authoritative sources of taxonomic information. Undescribed or unnamed species (e.g. defined operational taxonomic units) must also be meticulously documented to maximise consistent nomenclature among surveys and research groups. Archives of reference images from previous sampling campaigns have been established by numerous agencies across Australia and can serve as a useful benchmark for problematic sightings, which are kept up to date with recent taxonomic changes.

Consideration must be given to the location of stereo-BRUVs during deployment. Instruments should not be deployed inside shipping lanes, near fishing gear, or wherever they are likely to constitute or become a navigational hazard. At a minimum, deployment and retrieval locations should be recorded, with vessel location monitored at regular time intervals as a back-up. It should also be noted that deploying stereo-BRUVs on high relief reef or reef with tall algae can be very difficult or impossible. Potential entanglements with wildlife such as humpback whales also need consideration in some locations during certain times of the year, with interactions and encounters increasing as whale populations recover. Although this doesn't preclude the use of stereo-BRUVs, it can limit how they are deployed and attended.

Ensure all permits, safety plans and approvals have been obtained. Any research undertaken within Australian Marine Parks (AMPs) requires a research permit issued from Parks Australia. Other potential permits and approvals that may be required include; animal ethics, safety plans. Risk assessments and state specific research permits. See Appendix B for a list of potential permits required at the Commonwealth level.

Obtain sufficient data storage and backups, including hard drives to copy and backup memory card from each camera (*2TB hard drives or greater recommended*). Ensure each hard drive is formatted and labelled appropriately. NOTE: You will need to allow for two copies of every deployment, one working and one backup. A single 60-minute video is currently around 8 GB if you are using 30 frames per second (FPS). Ensure sufficient memory cards for cameras are packed (*one 64 GB per camera plus spares is suggested*). Use high speed for greater downloading speeds. Number the memory cards to allow easy identification in the field. Ensure the downloading laptop is operational; laptops with multiple USB 3 ports are recommended for greater download speed and the ability to download footage from multiple memory cards at the same time. Planning to backup each hard drive in the field is essential. This can be done using either single hard drives, a faster solid state hard drive, a RAID hard drive system, cloudbase, or server-based data storage if cellular coverage is available. This will avoid data loss due to hardware failure that can occur.

Test appropriate lights and additional sensors. If using lights or sensors (temperature, light/PAR, current, etc), check they are working and fully charged and have chargers, spare parts, and the required equipment for downloading data whilst in the field or upon return to the lab. The Hobo

Pendant temperature and light data loggers (UA-002-08) have been used with reliable results. The Marotte HS drag-tilt current meters (James Cook University; www.marinegeophysics.com.au/products/) can be fixed to the rear of the BRUV to move freely in the water column and record water temperature, current speed, and current direction.

Select and check appropriate camera settings are the same across all cameras (e.g. frame rate, video resolution, field of view mode, zoom, anti-shock sensors etc). Prior to any fieldwork, cameras should be checked to ensure they are serviced, cleaned, and calibrated (see below; note if a camera is moved or removed from its base plate it will need calibrating). It is important to note that small action cams (such as GoPro) do not perform particularly well in low-light conditions, especially with illuminated blue lights. If using such cameras, it is recommended that trials are undertaken prior to the sampling campaign. Clean and inspect housings for damage, check and replace o-rings if needed and lubricate with silicone grease. Ensure that housings are shipped with covers or protected in some way. This will prevent damage to the housing sealing surfaces and face plates.

Order sufficient quantities of bait well ahead of time. Due to differences in local supply, it is difficult to recommend a standardised baitfish. As a general rule a locally sourced, sardine-type, soft-fleshed, oily bait is recommended. This also reduces the likelihood of potential translocation of disease. Many BRUV studies from Australia have used pilchards (*Sardinops* spp.) as they are readily available, long lasting, and provide consistent bait size between field trips and studies (Dorman et al. 2012). Sourcing bait locally from factory discards (e.g. fish heads, tails and guts) is an attractive alternative for reducing costs and the ecological footprint of sampling. Allow at least 1 kg per planned BRUV deployment (recommended). When ordering, allow 20 % extra for repeating failed deployments.

Decide on the preparation and presentation of bait and consumables. Most studies use crushed or chopped bait presented in either a mesh bag or perforated PVC tubes. Bait arms should be angled towards the seabed and ideally in contact with the seabed so that the bait bag is not flapping in the current and so potentially disrupting fishes' natural inclination to be attracted to the bait (Cappo. pers. comm.). Ensure there are plenty of spare bait arms and bait bags or tubes. Bait arms may need to be reinforced with fibreglass rods if available or doubling up of PVC tubes. Having a number of rolls of duct tape and bags of cables ties is strongly recommended for running repairs.

Check ropes, bridles, floats/buoys for damage and ensure ropes are of sufficient length for the water depth that you are operating in (1.5:1 rope length to depth ratio). Float and rope configuration can also impact on deployment success. It is recommended that local trap fishers (e.g. lobster fishers) should be consulted on appropriate rope and float arrangement (Figure 5.5). Highly quality pot rope is recommended (e.g. New Zealand or Australian made). Check that there are a sufficient number and size of marker buoys and that they are coloured to make them visible at sea. Buoys should be marked with 'Research' and have each permit number. Make up spare ropes and floats in case gear is damaged or lost or damaged. Ensure sufficient weights are available for use at greater depths and in high currents. Typically double the weight is required at the front of the stereo-BRUV systems when deploying in deep water, but this arrangement will depend on local conditions and the frame design.

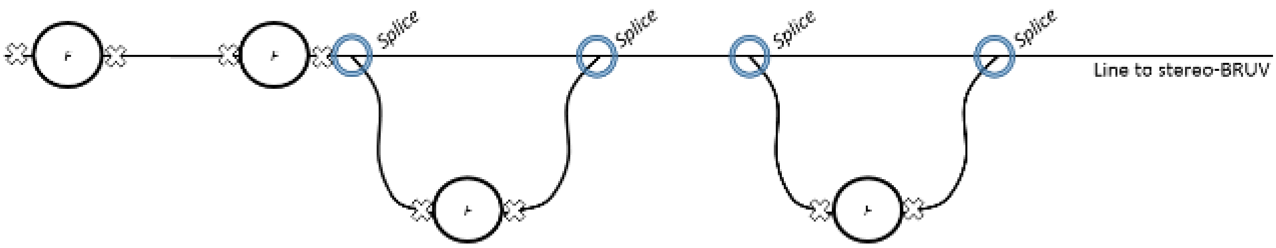

Figure 5.5 Example of top float (F) arrangement for using stereo-BRUVs.

Check spare parts kit, make sure tools are oiled and in working order. Spare parts are crucial for repairs and troubleshooting BRUVs in the field.

Sampling gear specifications should always be fully documented to achieve maximum transparency and comparability. This includes documenting the camera model, camera height above seafloor, camera separation, camera angle, camera field of view, underwater light lumens and colour, bait arm length and bait holder type.

5.5.1 Calibrating stereo-BRUVS

Stereo-BRUVS require regular calibration to ensure accurate measurements. The calibration process takes into account the base separation, camera angle and lens distortion all of which are unique to each camera, hosing and mount. Hence, each BRUV must be calibrated separately. Stereo-BRUVs should be calibrated using a 3D cube following recommendation by (Boutros et al. 2015)

It is ideal to calibrate each BRUV before and after each field campaign. This provides a backup in the event a camera moves or gets damaged during fieldwork. If cameras are swapped in the field due to damage or some other issue, the new cameras will require post-field calibration.

SeaGIS (https://www.seagis.com.au) have long been the primary provider of third-party calibration hardware and software, although alternative open-source packages have also begun to emerge, including the MATLAB Calibration Toolbox (http://www.vision.caltech.edu/bouguetj/calib_doc/) or the StereoMorph R package (https://cran.r-project.org/package=StereoMorph). For accurate and reliable stereo-calibration, SeaGIS software and calibration hardware is recommended.

5.5.2 Pre-survey checklist

	Task	Description/comments
□	Fish biologists and taxonomists engaged or identified	
□	Adequate benthic stereo-BRUV sampling design (see chapter 2)	
□	Deployment protocol determined, including methods for locating/tracking gear	
□	Appropriate permits obtained and printed copies made (on waterproof paper if necessary)	
□	Coordinates of sampling sites calculated and checked for safety hazards.	
□	Bait ordered in adequate quantities	
□	Camera settings checked and cameras calibrated	
□	Data storage needs identified and hardware purchased accordingly	
□	Metadata sheet prepared	
□	Gear shipment arranged	

5.6 Field Procedures

5.6.1 Arrival on site

1. Unpack and set up stereo-BRUV units. Check for any breakages that may have occurred during transportations.
2. Attach bait bags to bait arms ensuring there are sufficient spares.
3. Check synchronizing device (such as diode batteries).
4. Defrost bait for first day of sampling.
5. All cameras and equipment should be carefully checked to ensure setting or switches haven't moved during transportation.
6. Check camera batteries are charged, memory cards are formatted and that everything is labelled.
7. Discuss deployment plan and safety with the team and ensure the skipper has the coordinates for all sites.

5.6.2 Deployment

1. Fill bait bags with ~1 kg of crushed or chopped bait.
2. Check camera settings.
3. Check data sheet is ready (note site, camera numbers and memory card numbers).
4. Move the BRUV frame to a secure and safe position.

5. Attach lights and sensors if required.
6. Turn cameras on, check there is battery and storage space available.
7. Film data sheet or information board so that the site/location is identifiable at the beginning of the video.
8. Insert cameras into housings, check that the housing is dry and that there is no sand, hair or other objects obstructing the o-rings, and ensure there is a good seal and the clips are tight. Use shark clips to lock if necessary.
9. Attach ropes and buoys. Ensure the rope is free, coiled, and facing the correct direction to uncoil without hindrance. Ensure there is a 1:1.5 depth to rope (10 m of water = 15 m of rope). If there is a strong current you may need longer rope. It is also highly advised that there are several small surface floats followed by a large surface float.
10. Attach diode, or use clapper board, or alternative device to synchronise videos.
11. Attach bait arm.
12. With two people, lift the BRUV into position onto the gunnel or at the door of the vessel.
13. Push or throw the frame so that is clears the side of the boat.

    Important: If possible the skipper should keep the vessel directly above the site until the stereo-BRUV reaches the bottom and the crew gives the all clear to depart, i.e. all ropes clear of the boat. If the boat moves off the site before the cameras reach the bottom they will likely be pulled/tip over.

    To ensure it the BRUV lands upright in shallow water deployments (i.e. <40 m), tug the unit when it first hits the water to correct the horizontal orientation, then let it sink quickly until it reaches ~1-2 m from the seafloor (ask the skipper for the depth then count out rope lengths as you lower the BRUV to do this), then give it a good yank to make sure it is upright again and lower slowly for the remaining 1-2 m. You should also be able to feel if the BRUV lands well through the rope i.e. one jolt suggest a good landing compared to multiple when it hits bottom then keeps tumbling. A drop camera attached to the stereo-BRUV frame with a quick release system can also be used to ensure the stereo-BRUV lands upright and has a clear field of view. If the stereo-BRUV has fallen over or obstructed then you can simply lift it 1-2m and try lowering again. For deeper deployments, and in high current environments, weights should be added to ensure the frames do not drag or flip. It is recommended that when operating in depth >40 m, and using SeaGis BRUV frames, that two weights are added to the front first then one to the back if necessary. Also, if operating at depth and in high currents that you may need to feed the buoys and rope out in a broad circle around the sample site prior to dropping the BRUV in the water. This reduces the OHS risk associated with long ropes.
14. On the data sheet, note the exact time of deployment and depth off the depth sounder, include comments where necessary e.g. issues, weather conditions.
15. Mark a GPS waypoint and log the GPS coordinates of the deployment on the recording sheet.
16. Once all stereo-BRUVs are deployed it is important to move away from where stereo-BRUVs are set to avoid impacts of vessel noise on fish assemblages.

5.6.3 Retrieval

1. It is currently recommended that stereo-BRUV deployments are made for a minimum of 60 minutes to allow for comparisons with other studies. Therefore, the first stereo-BRUV can be retrieved after a minimum of 60 minutes from deployment.

2. The skipper should manoeuvre the vessel alongside the floats heading upwind or current towards the stereo-BRUV. A crew member will either gaff or grapple the rope near the floats and quickly hand haul in the slack rope.
3. The skipper should then manoeuvre the vessel directly above the stereo-BRUV. Once above the stereo-BRUV,the rope should be placed in the pot hauler or winch if available or pulled by hand.
4. It is important that the stereo-BRUV is not hauled until the vessel is directly above. This is to minimise the risk of snagging the rope or stereo-BRUV and to minimise damage to the habitat.
5. As the stereo-BRUV comes off the bottom the skipper should then manoeuvre the boat downwind or current to assist retrieval.
6. Only a crew member who is trained in using the pot hauler or winch, or under supervision by a trained crew member, should winch the stereo-BRUV.
7. The second crew member should help coil the rope that will aid in a quick redeployment.
8. Once the stereo-BRUV comes into view and is close to the boat, inform the skipper and slow the winch to ensure the bait and diode and facing away from the vessel.
9. The stereo-BRUV should be winched onto the deck or gunnel and carefully lowered down.
10. Dry the seals around the housing with a towel and carefully remove the cameras (if conducting surveys over multiple days, the O-rings will require cleaning and re-greasing with silicone at regular intervals, ideally daily).
11. Stop cameras recording, and turn them off. Store cameras in a dry, safe place until next deployment. If possible, turn off lights to conserve battery.
12. Remove memory cards and store.
13. If required charge or change camera batteries.
14. Either setup the stereo-BRUV for redeployment or secure on deck.

5.6.4 Retrieval of snagged or lost BRUV

In the event that a BRUV becomes snagged on the bottom the following procedure should be followed:

1. Stop retrieval.

2. Reposition vessel in opposite direction to initial attempt and recommence retrieval.

3. Repeat as necessary altering retrieval direction each time. Caution is needed as it is important to not allow rope to become worn either because of fouling on reef or at the pot hauler.

4. Some types of stereo-BRUV frames either bend or break at sacrificial pins (if fitted).

In the event that a stereo-BRUV is lost (rope cut or the current drags the camera system) the following procedure should be followed:

1. Attempt to grapple camera frame or rope. This can be challenging in deep water and will take time. A good technique for grappling in deep water is to attach weights every ~10 m on grapple line. Deploy the grapple line so that you encircle the stereo BRUV location. Weighting the grapple line ensures a higher chance of entangling lost stereo BRUV or its rope. Retrieve grapple and repeat as necessary.
2. If this fails an alternative approach is to locate lost stereo-BRUV using drop camera system or ROV if available. A depth sounder could also be used to rope and locate floats if submerged.

3. Lower the drop camera on the grapple rope to locate stereo-BRUV.
4. Winch as usual.
5. If the stereo BRUV system is not retrieved within 60 minutes, mark its exact location with GPS and/or anchored rope with buoys. Mobilize dive team (if in shallow enough water) or a ROV (for deeper waters) if available.
6. Notify Parks Australia of lost equipment if operating in an AMP.

5.6.5 Fieldwork data management

Data management and quality control is crucial for monitoring and comparisons between studies within AMPs. Following simple steps and using easily understandable and transferable metadata (Table 10) will enable simple harmonisation between studies.

1. Store used cards separately from unused cards to avoid confusion. If storing all memory cards to download, ensure they are clearly labelled and stored in a waterproof container. Memory cards should not be re-used or reformatted until data has been downloaded and a backup created.

2. If downloading occurs in the field it is important that all hard drives are clearly labelled in a way that can be discerned from the file name. For example: using the date, study name, and hard drive number, "176022_Groote_Island_stereo-BRUV_HD1".

3. Files should also be labelled in a way that can be discerned from the filename. For example, with site_year_month_day_study_cam1_cam2_L (folders on hard drives should follow a naming convention so that programs like "Bulk Rename Utility" can be easily used to rename all files with OpCode and camera number in the correct format).

4. Field metadata sheets should be transcribed/backed-up into a database or Excel spreadsheet which should be saved and backed up daily.

5.7 Post-Survey Procedures

5.7.1 Data management

Large amounts of data are created from BRUVS with large video files, field data sheets, and software output. It is therefore important to consistently label folders and files to easily locate data and to simplify analysis. We also recommend documenting the file naming and folder structure in a post-survey report (Appendix C).

5.7.2 Processing video footage

Fish annotations

It was recently recognised by the national BRUVs steering group that, where possible, species composition, abundance and length data for all species should be recorded. It is recommended that every fish within a MaxN frame should be measured. However, fish that occur in large schools, and are of similar size, can be attributed to binned length measurement using the Number field associated with each length in EventMeasure-Stereo (see below). It is important to document the range from camera as this is likely to change between regions/ecosystems. This information is included in the standard outputs of EventMeasure-Stereo and is imported by default into

GlobalArchive (see Section 5.7.4). Fish that occur in large schools can be attributed to binned length measurement using the Number field associated with each length in EventMeasure-Stereo.

There are several software packages available, but it is important the output from the analysis of data is in the same or similar formats to facilitate comparison of data between campaigns, studies, and organisations. The most commonly used annotation software is EventMeasure-Stereo from SeaGIS (https://www.seagis.com.au). If afforded then the EventMeasure-Stereo software is recommended, unless your organisation already has an alternative established stereo-video annotation workflow (e.g. AIMS). The essential information produced by such annotation software includes three main outputs:

- Point information
- Length measurements
- 3-D point information

Point information is typically used to calculate MaxN values, while length and 3D point information is used to calculate length and biomass metrics. EventMeasure-Stereo has established queries built-in to produce typical metrics over a user defined period within the footage. In addition, EventMeasure-Stereo annotation datasets held within GlobalArchive (http://globalarchive.org/) can be queried in a similar fashion to produce such metrics (see the manual for GlobalArchive).While there are a number of relative abundance metrics available, MaxN (maximum number of individuals for given species counted within the field of view at the same time) is the most widely accepted (Cappo et al. 2007, Harvey et al. 2007).

Type of fish length (e.g fork length or total length for fish and disc length for rays) should be clearly indicated as part of the adequate annotation information for each Campaign.

Habitat classification from field of view

Scoring of habitat information from the field of view is a relatively quick process and can provide extra information about habitat type. Classification of benthic composition and relief should be recorded from still image grabs for each deployment (e.g percent cover of benthos types) (Recommended). Collecting this information as continuous variables will enable regression approaches to be used to investigate the influence of habitat within the field of view on the fish assemblage. To enable comparisons between studies it is important that researchers use comparable classification schemes. Recent studies (McLean et al. 2016, Collins et al. 2017) have adopted the CATAMI classification scheme (Althaus et al. 2013) in a systemised approach to scoring habitat composition and relief from forward facing imagery using TransectMeasure from SeaGIS (https://www.seagis.com.au). This approach and standardised annotation schema have been documented in an open-access GitHub repository (Langlois 2017).

5.7.3 Quality control and data curation

Quality control and data curation are vital, but are potentially time consuming. These time considerations (and associated costs) should be considered during the survey planning stages.

All data corrections should be made within the original annotation files (i.e. within EventMEasure) to ensure data consistency over time. Four complementary approaches for QAQC of data are recommended:

- Analysts should first be adequately trained by completing deployments for which a species composition and density are known to which they can be compared.

- Once the first annotation for a deployment is completed, a different analyst should view each MaxN annotation to double check the species ID and abundance estimates.
- Footage from any previously unrecorded (i.e. range or depth extensions) or unidentifiable species should be sent to the project taxonomist for formal ID. It is important to send footage clip rather than still images.
- R workflows are provided in a GitHub repository to enable comparison with regional species lists and likely minimum and maximum sizes for each species (Langlois et al. 2017).

It cannot be stressed enough that any corrections should be made to the annotation files before data is exported to GlobalArchive or other repositories (i.e. only QC-d annotations should be publicly released).

A national BRUV steering group has been set up to oversee a nationally coordinated BRUV monitoring program (Table 5.1). Any new BRUV deployments should be discussed with this steering group to ensure that, where possible, they can be integrated within the national program (*Recommended*).

Table 5.1 Key contacts in national BRUV steering group, as of Jan 2018.

Name	State	Organisation
Euan Harvey*	Western Australia	Curtin
Tim Langlois	Western Australia	UWA
Neville Barrett	Tasmania	IMAS
Jacquomo Monk	Tasmania/Victoria	IMAS
Alan Jordan	New South Wales	NSW DPI
Hamish Malcolm	New South Wales	NSW DPI
Daniel Ierodiaconou	Victoria	Deakin
Charlie Huveneers	South Australia	Flinders University
Leanne Currey	Queensland	AIMS

***** Chair

5.7.4 Data release

GlobalArchive (www.globalarchive.org) is a centralised repository for stereo- and single-camera fish image annotation data, in particular from Baited Remote Underwater stereo-Video (stereo-BRUVs) and Diver Operated stereo-Video (stereo-DOVs). A user manual for GlobalArchive is available in an open-access GitHub repository. Metadata should be made publicly available via GlobalArchive as soon as possible after survey completion and data QA/QC and validation. This should include positional data, as well as the purpose of the sampling campaign, the survey design, all sampling locations, equipment specifications, and any challenges or limitations encountered. Annotations can also be uploaded once complete. Spatial metadata from GlobalArchive data will in the future be harvested by the Australian Ocean Data Network, and the metadata will accordingly be available on their national portal. Until this is done, metadata should be published on both GlobalArchive and AODN to ensure data discoverability *[Recommended]*.

There is currently no national repository for BRUV imagery so we recommend following agency-specific protocols to ensure public release. A national marine imagery repository (including for BRUV imagery) will be scoped in 2018 and updates provided in Version 2 of this field manual.

Following the steps listed below will ensure the timely release of video and associated annotation data in a standardised, highly discoverable format.

1. Immediate post-trip reporting should be completed by creating a metadata record documenting the purpose of the BRUV sampling campaign, the survey design, all sampling locations, equipment specifications, and any challenges or limitations encountered. This can be done far in advance of annotation (scoring) of raw video which is time-consuming and often does not occur for some time following completion of sampling.

2. Publish metadata record to the Australian Ocean Data Network (AODN) catalogue as soon as possible after metadata has been QC-d. This can be done in one of two ways:

   - If metadata from your agency is regularly harvested by the AODN, follow agency-specific protocols for metadata and data release.
   - Otherwise, metadata records can be created and submitted via the AODN Data Submission Tool. Note that user registration is required, but this is free and immediate.

   Lodging metadata with AODN in advance of annotation data being available is an important step in documenting the BRUV campaign and enhancing future discoverability of the data.
3. Annotate video (fish counts and length) using EventMeasure or similar software.

4. Upload annotation data and any associated calibration, taxa and habitat data to GlobalArchive.

5. Upload raw video data to a secure, publicly accessible online repository (contact AODN if you require assistance in locating a suitable repository for large video collections).

6. Add links to GlobalArchive campaign and raw video storage location to previously published metadata record. You may also wish to attach or link a copy of the annotation data directly to the published metadata record.

7. Produce a technical or post-survey report documenting the purpose of the survey, sampling design, sampling locations, sampling equipment specifications, annotation schema, and any challenges or limitations encountered. Provide links to this report in all associated metadata. See Appendix C *[Recommended]*

5.8 Field Manual Maintenance

In accordance with the universal field manual maintenance protocol described in Chapter 1 of the Field Manual package, this manual will be updated in 2018 as Version 2. Updates will reflect user feedback and new developments (e.g. data discoverability and accessibility). Version 2 will also detail subsequent version control and maintenance.

The version control for Chapter 5 (field manual for Benthic BRUVs) is below:

Version Number	Description	Date
0	Submitted for review (NESP Marine Hub, GA, external reviewers as listed Appendix A.	22 Dec 2017
1	Publicly released on www.nespmarine.edu	28 Feb 2018
2	Relevant updates, including Data Release sections based on NESP, AODN, IMOS, GA, and CSIRO projects	Early 2019

Table 5.2 Example metadata sheet for benthic stereo-BRUV fieldwork. Left and right memory card numbers must be recorded for each camera pair.

Date	Site	BRUV#	Cam. Left #	Cam. Right#	Time in	Location in	Time out	Depth	Comments
2017-10-25	SITE-A	15	12	10	08:00	(115.12E; 32.54S)	10:15	95m	

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