# Using mono- and stereo-BRUVs to monitor marine fauna in Namibia: Standard Operating Procedures

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A report of the Namibia's Rays and Sharks (NaRaS) project

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## 1. INTRODUCTION

There has been limited research on marine species and ecosystems in Namibia. Namibia's marine environment can be a challenging place to work, with strong winds, sometimes large swells and cold, turbid waters. The majority of marine research in Namibia to date has focused on commercial fish species. There is therefore a dearth of data on the distribution of coastal and offshore habitats and seabed types, as well as the spatial and temporal variation in marine fauna. These types of data are essential for identifying critical habitats for species of conservation concern, to inform the design of marine protected areas.

Comprehensive monitoring of marine ecosystems, particularly in deeper regions, is difficult. While there are methods like longlines and bottom trawling or dredging, for assessing deep-water marine ecosystems (Santana-Garcon et al. 2014; McLean et al. 2015), concerns for already-impacted marine ecosystems encourage the use of non-destructive methods (Murphy and Jenkins 2010). Various non-destructive, non-extractive methods have been used to study fish assemblages in marine and estuarine environments (Ghazilou et al. 2019), of which the most widely used are scuba based underwater visual census (UVC), diver operated video (DOV) and baited remote underwater video systems (BRUVs). Remotely operated vehicles (ROV) and towed cameras can also be used to survey demersal fishes and are increasingly being used in polar and deep-sea environments (Sward et al. 2019; Langlois et al. 2020). These methods, however, necessitate specialised vessels and present numerous logistical challenges, making them a less practical option in developing countries with limited capacity and resources.

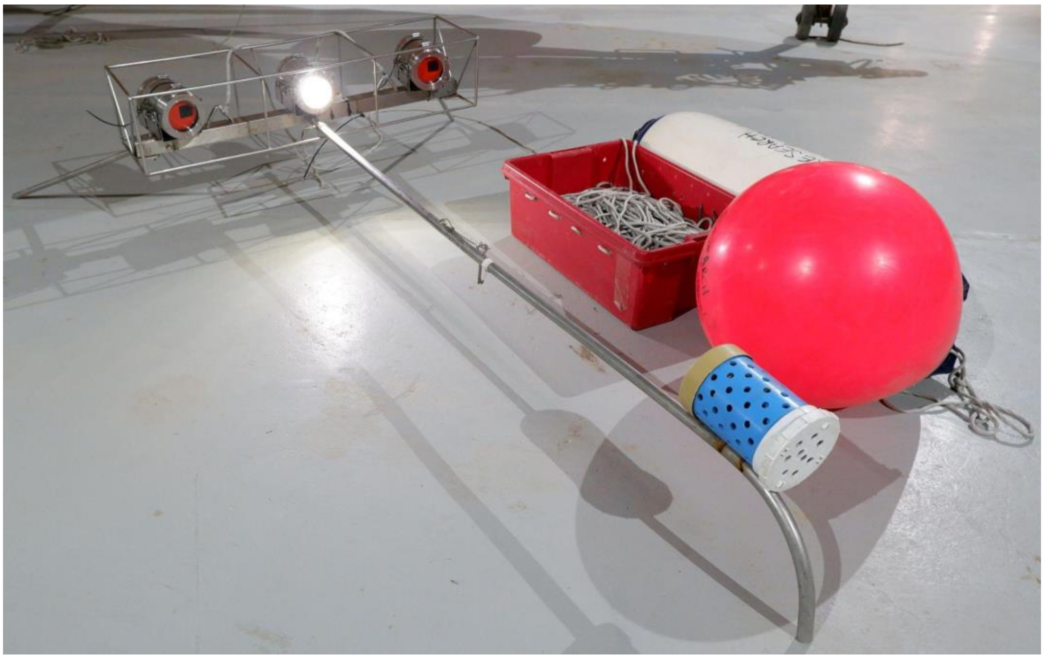
Mono-BRUVs and stereo-BRUVs (hereafter referred to as BRUVs) collect data in the form of video recordings of the marine life and seabed in the area where the system is deployed. Multiple deployments in an area can generate a dataset on the diversity of marine life and seabed types, providing location-specific data which can be compared across a range of sites, depth ranges and ecosystems to develop a more complete picture of biodiversity in a region. They have become a popular alternative to methods using divers, and have the potential to collect data at deeper depths than those that can be reached by divers, and in areas where conditions may be unfavourable for divers (e.g. where sea conditions can be challenging and where the underwater visibility is highly variable). BRUVs are a non-extractive technique, meaning they have little impact on the ecosystem being studied, and have been shown to offer a non-invasive alternative to longline surveys for monitoring broad trends in the relative abundance of sharks (Brooks et al. 2011; Santana-Garcon et al. 2014; McLean et al. 2015). They are thus an ideal sampling platform to use in marine protected areas (MPAs).

Stereo-BRUVs were piloted in the Namibian Islands Marine Protected Area (NIMPA) between 2022 and 2024 by the NaRaS project, and proved a valuable method for monitoring marine fauna. The use of mono- or stereo-BRUVs has thus been recommended for future monitoring of the NIMPA and for baseline assessments of any future candidate marine protected areas (Leeney 2024). This document should provide anyone wishing to use BRUVs for monitoring and research purposes with all the guidance they need to prepare, deploy, and retrieve the equipment. Much of the guidance is based on standard operating procedures developed and shared by the South African Institute of Aquatic Biodiversity. The guidance provided in this document specifically assumes that any further BRUVs datasets collected in Namibia should align with the existing data collected between 2022 and 2024 by the NaRaS project, to allow for comparison amongst datasets and over time. This document also provides guidance on how to analyse and store the datasets collected over time, and how data should be used to inform management and monitoring decisions, both for MPAs and in other contexts.

## 2. STEREO-BRUVs

### 2.1 INTRODUCTION

Stereo-BRUVs consist of two cameras inside waterproof housings, attached to a base-bar and encased within a frame with a baited container in front of the cameras. As well as recording relative abundance values for marine fauna, facilitated by both mono- and stereo-BRUVs, the stereo system allows for fish lengths to be measured. There are two types of stereo-BRUVs used for sampling: pelagic stereo-BRUVs and benthic stereo-BRUVs. Pelagic stereo-BRUVs set the camera systems at a predetermined depth in the water column, whilst benthic stereo BRUVs are set on the seafloor. This section provides details on the methods for working with benthic stereo-BRUVs only.



A tripod stereo-BRUV system. © South African Institute of Aquatic Biodiversity.

**2.2 CALIBRATION**

Stereo BRUVs require camera calibration to ensure that any length measurements taken using the footage captured by both cameras are accurate. It is recommended to perform calibration both before (pre-calibration) and after (post-calibration) a field trip. This practice serves as a precaution in case one of the cameras is damaged or shifts during fieldwork. If cameras are replaced for any reason during the field trip, the system(s) with which those cameras are used will need to be calibrated after the field trip. During calibration, factors such as the distance between the bases of the housings, the angle of each camera and any lens distortion are considered, all of which vary for each camera, housing, and mount (Langlois et al. 2018). For this reason, it is necessary to calibrate each stereo-BRUV system separately.

The calibration of stereo-BRUVs requires a clean swimming pool. Since appropriate facilities are not always available near to the sites where fieldwork takes place, it is important to plan for a day for calibration activities, both prior to and after each field trip and ensure that the swimming pool is reserved for this purpose.

**Equipment and software**

Refer to Appendix I for the equipment list for calibration and sources for the equipment and software.

Calibration cube. © SeaGIS.

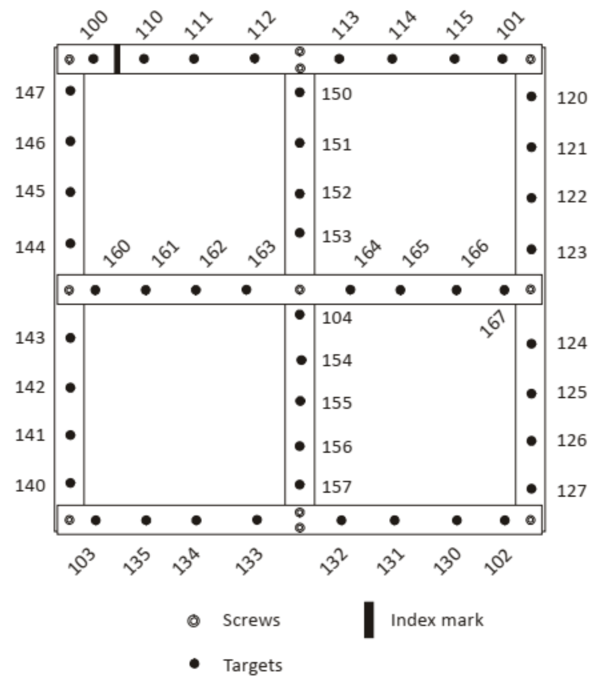
**Calibration: Analyses**

- Download the video files recorded during the pool calibration session.
- Open the CAL software and create a new project.
- Enter a name for the new project (YY-MM_Project name_Cams#L&Cams#R_pre-cal/post-cal).
- The CAL software will automatically run you through the next steps required.
- Ensure all the videos are in a single folder (named with ‘precal’ or ‘postcal’ as appropriate, and the date), with the right camera file(s) labelled with ‘R’ after the filename.
- Set the picture directory.

- Load the camera files. For GoPro cameras, Hero5 black **.CamCAL files are used.
- Load the calibration object points file. (**.PtsCAL).
- Load the video files. Click ‘Picture’, then ‘left’ or ‘right’, then ‘Define movie sequence’.
- Ensure that the left video and the right video are indeed the left and right videos by playing each video and checking the angle of the view.
- Create a new measurement file. Click ‘Measurement’, then ‘Write measurement file’. Name this file as <u>YY-MM_Project name_Cams#L&Cams#R_pre-cal/post-cal</u>.
- Synchronise the videos by finding the frame where there is a ‘chop’ on the cube, in both the left and right videos. Get both videos to a frame you are confident represents the same point in time in each, and click ‘Lock’.
- Start the analysis. You will need to measure a minimum of 40 images (20 images in each of the L and R videos).

**The CAL cube**

All points on the front face of the cube (nearest to the camera) are numbered in the 100s, while those on the back face (farthest from the camera) are in the 200s. The numbering sequence is the same on both faces, with the first digit indicating the face number (1 for the front and 2 for the back). Point 104 exists only on the front face, and there is no point 204 on the back face.




The numbering of the points (‘targets’) on the CAL cube. © SeaGIS.

- In the videos, the cube will be moved to give you four rotations. You must measure at each rotation. This is done by zooming in on the white stickers. Holding in the SHIFT key and left clicking on the sticker.
  <u>Note</u>: The order in which you measure each sticker is important. Likewise, the numbers that appear once you have measured a sticker are important and should be checked. For each point on the cube, you should select the relevant white sticker in the left video and then the same number sticker in the right video.

- Start with the sticker that lies to the left of the white line sticker. This should be number 100. Move in a clockwise direction.
- The second measurement should be the last sticker on that same line and should be number 101. The third should be number 102, the fourth should be number 103 and 104 should automatically appear in the centre of the cube.
- Click 'Resect' and 'autofind'. Ensure that the number of measurements is higher than 30. If not, try to manually find at least 40 images, preferably more.
- Repeat this for each rotation of the cube.
  Note: Look out for centroiding errors, randomly placed points (created by the CAL software but that do not represent one of the white stickers on the cube), and incorrect numbering on the first four points.
- To complete the process, click on 'Adjustment', then 'Compute bundle adjustment'. Double click on the object point summary and ensure that the precision is over 1:8000. If not, include more images of measurements and try again. Check that the adjustment has succeeded.

If the Adjustment fails:

- Click on 'Measurement' and 'View/delete image measurements'. Double click on the rejected column so that all of the rejected error messages come to the top. Hold the shift key down and click on the first and last rejected error messages. Click delete and close.
- Click on 'Measurement', then 'Find targets in all images'.
- Re-attempt bundle adjustment as above. Ensure that the precision is over 1:8000. If not, include more images of measurements and try again. Check that the adjustment has succeeded.
- If the adjustment still fails, click on 'Measurement', then 'View/delete image measurements. Double click on the rejected column so that all of the rejected error messages come to the top. Hold the shift key down and click on the first and last rejected error messages. Click delete and close.

- Once the Adjustment has succeeded, accept the results.

- To generate stereo files, click on 'Measurement', then 'Stereo constraints', then 'Configure stereo constraints'. Click 'Automatic' and make sure that the number of left measurements equal the number of right measurements.
- Click on 'Measurement', then 'Stereo constraints', then 'Estimate constraints'.
- Click on 'Measurement', then 'Stereo constraints', then 'View stereo-constraints'.
- Finally, click on 'Measurement', 'Stereo constraints' and 'Export stereo camera files'. CAL will automatically ask you to save the left cam file. Save it as YY-MM_Project name_CAM#L_pre-cal/post-cal. Likewise CAL will ask you to save the right cam file; save as YY-MM_Project name_CAM#R_pre-cal/post-cal. These files are essential for enabling stereo measurement functionality in the EventMeasure software.
- Save the Measurement file (ObsCAL) as YY-MM_Project name_Cams#L&Cams#R_pre-cal/post-cal.
- The object points (PtsCAL) is automatically saved. So are the last cam files (CAMCAL).

## 2.3 FIELDWORK

### Equipment

Refer to Appendix II for the equipment list for stereo-BRUVs fieldwork.
Refer to NNF safety documents for all required safety equipment that should be present on the research vessel for every trip. All team members working at sea should wear a lifejacket.

### Vessels and safety at sea

If stereo-BRUVs are to be deployed and retrieved by hand (which is only feasible if deploying in waters up to 35 m deep and in areas and conditions where extra weighting in the BRUVs frames is not required), a small vessel without a winch can be used. Any vessel should have adequate deck space to allow for a team of three to four people (excluding the skipper) to assemble at least one stereo-BRUVs at a time and prepare the bait. The vessel must also have enough space - on deck, in the bow, below deck or in other storage compartments - for up to three stereo-BRUVs frames and the rest of the equipment required for working at sea. This equipment and the personal items of the crew should ideally be stored away from the deck, so it does not interfere with the deployment and retrieval activities.

For deeper deployments or to reduce the physical labour involved in retrieving stereo-BRUVs, a vessel with a winch is necessary. However, there must be an experienced winch operator available at all times, preferably someone other than the skipper.

The range of the vessel (how far it can travel in a day - based on its maximum speed of travel and rates of fuel consumption) will determine the area in which sampling can be conducted. If a large area is to be sampled including regions far from any safe harbour, it is recommended that a larger vessel is used. This should be a vessel that can provide adequate sleeping arrangements for the whole crew and that is suitable for spending multiple days at sea in the challenging conditions often experienced in Namibian waters.

Prior to each day's fieldwork, the area in which sampling will take place should be determined, and the skipper should then calculate the fuel required to reach that area, work around the area (which for BRUVs work, involves a lot of small drives in between BRUVs deployments) and then to return to the harbour. At least 25% extra fuel above the calculated required amount should be brought on every trip, in case of emergencies.

### Preparing for a day at sea

- Inform the land-based contact and marine safety team on the plan for the day.
- Make sure all the lighting and GoPro batteries are fully charged. GoPro batteries show orange when charging and green when fully charged, the light batteries show red when charging and green when fully charged.
- Make sure the LED lights are functioning correctly, connect the battery to the light and inspect that all lights are working and that the o-rings are clean, free of cracks or damage and have silicone grease on them.
- Make sure the bait is defrosted. Remove the bait from the freezer the night before a day at sea, to allow it to defrost overnight.
- Ensure the silica crystals are dry, by drying them in a microwave (Usually requires c. 3 mins on a 'speed defrost' setting, depending on the microwave - start with one minute and assess the colour change to judge when they are adequately dry). They are blue in colour when they are dry and ready for use, and pink when they contain moisture. Store in a sealable plastic

container once they have been dried out, but ensure they have cooled before sealing the container.
- Ensure you have blank/clean data sheets (Appendix IV) printed and already attached to the clipboard. Additional blank data sheets can be brought along in a plastic folder. If you have already completed one or more BRUVs deployments, check the sample number of the last BRUVs sample you collected, and enter the next sample number on the first line of your datasheet for the following day.
- Ensure the data from memory cards to be used have already been downloaded and backed up (this is usually done on the same day that the data were collected). The same memory cards are used for each day at sea, requiring them to be reformatted each time.
- Activate the temperature loggers on the BRUVs, the night before or morning before fieldwork. The steps required will depend on the model of temperature logger used - refer to the manufacturer's website or the manual for the logger, for guidance.

**Deploying and retrieving stereo-BRUVs**

Tip for working efficiently at sea: Allocate duties on-board to minimise confusion. A minimum of three people (excluding the skipper) is recommended for all BRUVs work; a field team of four is ideal. One person should handle the bait for the entire trip, and should not handle any of the electronic equipment to avoid getting fish oil on it. One or two individuals (depending on the size of the crew) can set up the BRUV system for each deployment, handling memory cards and batteries, and starting the cameras. One person can deal solely with ropes - tying the appropriate length rope onto the system, as well as lowering each system and hauling it up at the end of the deployment, and coiling the ropes properly. One individual can call out the deployment details (GPS position, depth and time) from the boat's GPS/ echo sounder, and another individual, the scribe, can record those details. The scribe and the person calling out the deployment details can be the same people that set up the BRUVs.

- Load everything on the checklist that you will need for the day, onto the vessel.
- Inform the skipper of the intended area of work for the day. Ask for any updates on sea conditions and forecast, and change the plan if necessary.
- Inform the land-based contact and marine safety team on the plan for the day and expected time of return to shore.
- Each crew member must don their life jacket before they step onto the vessel or begin loading equipment onto the vessel.
- Load equipment on the boat and head out to the study area.
- Once the first deployment site of the day is reached, assemble one stereo BRUVs by attaching the BRUVs legs and bait arm.
- Depending on the depth of water at deployment site, and sea conditions (swell and current) attach the corresponding rope length to the BRUVs and the other end to the buoys (tie it to the circular buoy, which in turn is attached to the fender), using a bowline knot.
- Prepare the bait by crushing it in the bucket, using the bait stick, until the oils are released from the fish and a fairly homogenous, thick paste has resulted. Fill the canister with 1 kg of bait, then attach the bait canister to the bait arm.
- Remove the LED light from the light housing, insert the silica crystals in the light housing, attach the battery to the circuit board connection and secure the battery in place with rubber bands (make sure the o-rings on the light housing are clean and have silicone grease on them). Insert the LED light back in the light housing and secure it with a cable tie. (You can do this step right before you deploy the BRUVs in the water, to conserve the light batteries).

- Prepare the cameras: into each camera, insert a battery and memory card (note the card number used for each camera – see next step). Turn on the camera and adjust settings as detailed in the following step.

| |
|---|
| Video settings on GoPro should be set to:<br>Resolution (RES 1080p) Frames (FPS50), Field of view (Linear, FOV LINR)<br>Swipe down on screen, select preferences, scroll down and make sure: Auto off is set on never, Video format is PAL.<br>Scroll down to Format SD card to erase all data before recording. |

- On the datasheet for the day, record the date, fieldtrip code, project code, location, wind speed, wind direction, swell height, cloud cover, and rain.
- For each sample, the sample code, site (if it has a name), camera numbers, memory card numbers for left and right cameras, bait type, bottom depth, current, time in and time out, GPS coordinates, and comments should also be recorded.
- Once ready, press the record button on the cameras, record the information on the data sheet on the video (read out sample code and camera number aloud, so that it is recorded at the start of the video sample) and insert cameras into the camera housing on the BRUVs.
- Prior to deploying the BRUVs, ensure a 'chop' is made on the bait arm or somewhere visible on both cameras. This should be a clear movement (e.g. a finger or the edge of a hand making contact with the bait arm, then swiftly pulling away from it) which will allow for a frame to be identified in the footage of both cameras which represents the same moment in time. This is essential for the synchronising of the left and right videos during the analysis stage.
- Deploy the BRUVs by lifting carefully off the deck and placing it on the gunwale, then lowering it slowly to the seabed. If possible, ask the skipper to turn on the down scan function on the depth finder and alert you when the BRUVs is 2 m off the seafloor. At this point, lower the BRUVs very slowly until you feel the rope slacken. This means the BRUVs is on the seafloor.
- Record 'time in' (time when the BRUV touches the seafloor), depth, latitude and longitude.
- The remainder of the rope attached to the BRUVs and the surface buoys should be thrown overboard, some distance from the vessel, to ensure that the line is not entangled in the propellors as the vessel moves away. Observe the surface buoys to ensure they are floating and not being pulled under (which would suggest that the rope on the BRUVs is too short).
- Move on to the next deployment location and return to each deployment after 60 minutes, to retrieve the BRUVs. Ideally 3 BRUV systems are used each day and are deployed and retrieved in sequence.
- When the boat is at the position of the deployed BRUVs, carefully lean over the edge of the boat, grab one of the surface buoys and pull it onto the boat. Then start pulling in the slack on the rope.
- Ensure that you are directly above the BRUVs before you lift it off the seafloor. This may require some communication between you and the skipper to manoeuvre the vessel into the right position, so that the rope attached to the BRUVs is vertical in the water, rather than running into the water at an angle. Lifting the BRUVs when not directly above the system may drag the BRUVs along the seafloor before it lifts, which can cause damage to the equipment or the habitat, and may occasionally cause the BRUVs to become stuck on the bottom.
- If retrieving by hand, use a safe retrieving procedure: use gloves, keep a straight back, never wrap the rope around your hand/fingers, ensuring that the hauled rope lands on a clear space on the deck and does not get wrapped around anyone's feet, and always have a second person to provide support or take over the lifting if necessary.

- Pull the BRUVs onto the boat (record time out as soon as the BRUVs is on the boat), stop both cameras by pressing and immediately releasing the record button. Dry each camera housing using a cloth, remove the cameras from the housing and inspect the footage by swiping from left to right on the GoPro screen, then pressing play. This allows you to confirm that the deployment went well and has resulted in footage; it also allows you to identify any potential problems, such as the BRUVs flipping over or landing upside down, which can be remedied in future deployments. After inspecting the footage, switch off the cameras, remove the SD card and place it into the used memory cards container. Remove the battery from the camera and place it into the used battery container.
- Detach the bait canister from the bait arm and replace the bait, then attach the bait canister to the bait arm. Repeat the process of setting up the cameras for your next deployment, using a fresh battery and an unused memory card.
- The battery in each light can be replaced after 2 or 3 deployments. Ensure that used light batteries, once removed from the ligt, are stored separately so they are not accidentally re-used.
- If any equipment breaks or you notice wear and tear on any part, make a note of it on the day's metadata sheet and ensure that the issue is addressed as soon as you get back to the office. For less urgent issues, ensure they are noted to be addressed at the end of the field trip.

At the end of each day at sea:

- Disassemble each BRUVs as soon as it is brought on board, and stow the parts away safely for the journey back to harbour. Remove the ropes from the BRUVs and buoys.
- Once you are at your base, put the ropes out to dry in the sun. Rinse the gloves and any cloths used to clean cameras or camera housings, and hang them out to dry. Saltwater can corrode many materials over time, so wipe down any other equipment which was exposed to saltwater or sea spray, and ensure it is dry and clean before it is packed away.
- Recharging of camera and light batteries should commence as soon as possible. This is especially important if you plan to go to sea the next day.
- Download the data from the memory cards onto the hard drive, label the folders according to the sample code and which side of the camera (i.e. 24-02_NAR025_L and 24-02_NAR0025_R). Where L= left side camera and R= right side camera.

**Troubleshooting: Fieldwork**

***BRUVs is lifted periodically from the seafloor/ is dragged along the seafloor during the deployment.***

Caused by: Big swells; BRUVs rope being too short; BRUVs not being appropriately weighted.
Impacts: This can cause acoustic disturbance to marine life (which may reduce the number of detections during the sample) and can also damage the seafloor. If the moving system disturbs sediment, this can also cause temporary reductions in visibility which will affect the analysis. The risk of the system getting stuck in crevices in the seafloor may also increase, depending on the bottom type.
Solutions: When deploying your BRUVs, make sure to use the appropriate length of rope based on the depth at the deployment site. This means accounting for the depth at the site, several additional metres in case of swell, and several extra metres in case the system moves to a slightly deeper location. For instance, if deploying in water that is 13 m deep, utilise a 20 m rope to prevent the BRUVs from being lifted up by swells.

***BRUVs landed upside down or flipped over during deployment***
*This will be picked up if the video sample is checked by quickly scrubbing through the video on the GoPro, after the BRUVs is retrieved and before the camera is set up for the next deployment. Detecting the first time this happens on a sampling day will allow you to make changes to subsequent deployments and hopefully avoid this issue in other samples.
Caused by: A BRUVs landing upside down may be caused by the system becoming entangled in the rope on the way to the seafloor and not landing with the legs pointing downwards, or landing on the edge of a sharp drop on the seafloor and then slipping and inverting. A BRUVs inverting mid-deployment may be caused by large swells, strong surge underwater or the BRUVs not being appropriately weighted.
Impacts: An upside-down BRUVs may still record useful footage, but depending on the angle it lands at, it may provide a limited view of the water column. This restricts the area within which marine fauna can be detected by the analyst.
Solution: To avoid the BRUVs landing upside down, use an echo-sounder on the boat and always avoid deploying BRUVs in areas where there are sharp changes in depth. To avoid the system inverting mid-deployment, use an appropriate length of rope (see notes above). If footage from an initial deployment suggests a strong bottom current or strong surge, consider attaching additional weight (metal bars or dive weights which can be attached to the base bar of the frame) to subsequent deployments.

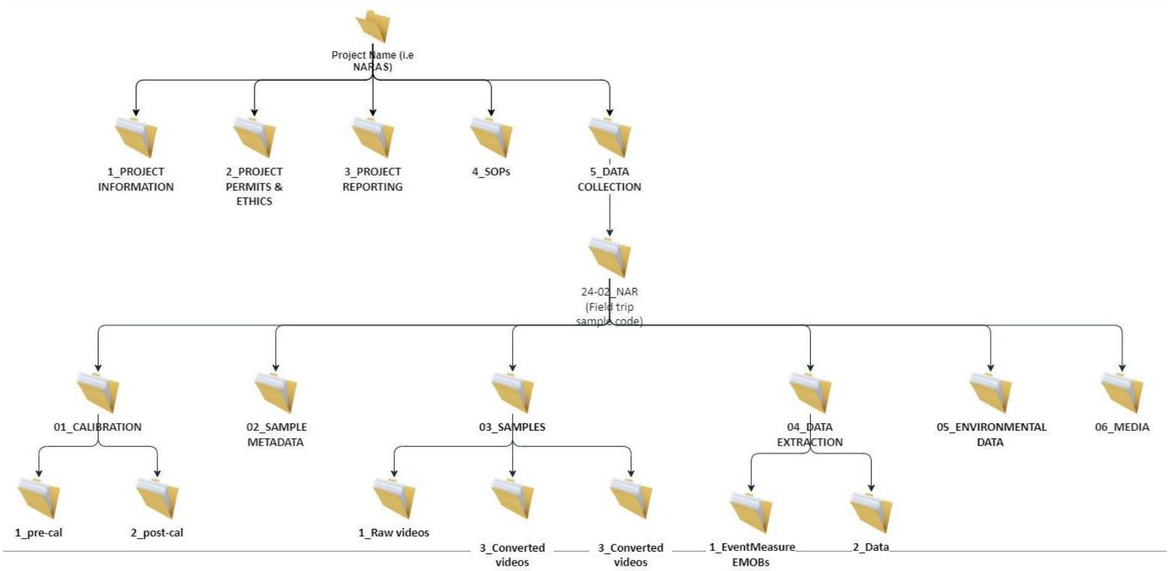
## 2.4 DATA MANAGEMENT

See Appendix III for a list of equipment required for the data downloading and management stage.

The data management phase of the BRUVs fieldwork is a very important one. A folder structure replicated for each field trip allows for files from previous field trips to be easily located by all team members.

The most important outputs from BRUVs fieldwork are:
- A metadata spreadsheet into which each day's metadata (data on the sampling trip and on each BRUVs sample collected) are entered. There will be a separate metadata spreadsheet for each BRUVs fieldtrip.
- The raw video files from each BRUVs deployment.
- Below is a flowchart showing how to name the folders and their arrangement.

All video samples should be saved in the folder '1_Raw videos'. Within that folder, a new folder should be created for each BRUVs sample, named according to the sample code and whether it was right or left camera (i.e. '24-02_NAR008_L' and '24-02_NAR008_R' would be the folders for video samples collected during a field trip that started in February 2024, for the left (L) and right (R) cameras). The multiple video files resulting from each BRUVs sample (GoPro cameras usually create multiple video files of about 15 mins long each, which the EventMeasure software then stitches together to create a single 60-minute video for analysis) will be saved in these folders. When beginning video analysis in EventMeasure, ensure all video files from both the left and right cameras for that sample are in the same folder. To do this, first add the letter 'R' to the end of the file name of each video file from the right camera, before then cutting them from the R folder and pasting them into the L folder. This distinguishes the left and right camera video clips and makes it easier to select the correct clips when loading videos in EventMeasure.




**Temperature data**

If there are temperature data loggers attached to the BRUVs frames, the temperature data should be downloaded at the end of each field season. However, if there are long gaps in the field season, during which BRUVs are not being deployed, it is recommended that the loggers be turned off to conserve their batteries. Remember to turn them back on prior to the next deployment.

**Backing up data**

It is essential to ensure that all data collected during a BRUVs study are backed up. Essentially, they should be saved on at least two separate devices (e.g. on two separate hard drives, or a laptop and a hard drive, but video files will quickly fill up a laptop's memory) to ensure data redundancy. This applies to every video sample file as well as all temperature logger data, photographs of metadata sheets and excel spreadsheets containing metadata. Likewise following the analysis of BRUVs samples, the resulting analysis output files from EventMeasure (EMOB files) should be backed up. External hard drives cannot store data indefinitely and their functionality and life-span is affected by temperature and humidity. Saving all monitoring data on an online server, whilst costly, provides an additional level of data redundancy.

## 2.5 ANALYSIS

See Appendix II for a list of equipment that should be available for downloading data and their analysis. Once EventMeasure has been installed onto the computer to be used for analysis, a software key will be required to open and work in EventMeasure.

- Open EventMeasure and open a new measurement file.
- Load the video files for the left and right cameras, and load the camera files that resulted from the calibration process.
- Sequence configuration: There are usually more than one video files for each camera (a 60-minute deployment usually has 3 to 5 video files associated with each camera), so additional video files must be loaded in the correct order, so that the full 60-minute sample will play and be available for analysis.
- Load the species file - 'ATLANTIC FISHBASE CSAAB.txt' is the most appropriate file for Namibian waters. This ensures that the names of all likely species encountered in the videos will be available for selection when marking species in the video samples.
- Enter the data on the deployment e.g. sample code, name of analyst, depth.
- Synchronise the left and right videos - this is an important step to allow analysis to proceed. Once a frame that represents the same moment in time has been selected for both left and right cameras, click the 'lock' block so that the videos now play synchronously.
- 'Time on seafloor' denotes the duration when the BRUVs have settled on the seafloor, and any disturbance or debris has cleared. This marks the starting point for your 60 minutes of analysis. To capture the time on the seafloor, create a 3D point by left-clicking on any spot in the left video, causing a red cross to appear. Repeat this process on the right video. Then, right-click on the red cross in the left video and select 'Add 3D point'. Enter the phrase 'Time on seafloor' into the comment box and confirm by clicking 'OK'. The time on seafloor can be found on top of the left video in brackets.
- Complete additional information in the information field values - time on seafloor, video duration, visibility (or leave until end of analysis), bottom type (select from the following standardised options: *a) Sand, (b) Patch-reef high, (c) Patch-reef low, (d) Reef high, (e) Reef low, (f) Sand inundated reef, (g) Mud, (h) Kelp forest, (i) Seaweed garden*), % water column, % obstruction.
- Extract a survey area image and habitat image and save it in the folder 5_Environmental data.
- Define the Analysis period by right-clicking anywhere within the left video, then select 'Period definitions' followed by 'Add new period start'. Enter the text 'Analysis' into the white box of the input dialog and confirm by clicking 'OK'. A new time will appear beside the Toggle view button, showing the name of the period as 'Analysis' and the time as 0.0000 minutes. Your analysis begins now, and you'll conclude it once this number reaches 60.000 minutes.
- Begin analysis.

Video analysis involves watching the footage for 60 minutes, marking all species that can be seen and recording how many species can be seen in one frame. This involves a number of steps, as follows:

Play the video. Watch the video and slow the video down if necessary (UP/DOWN keys).
If you see a fish, move through the video frame-by-frame (using LEFT/RIGHT keys) until you have the best possible side-on view of the fish. When you are happy with the view, click 'Close player' and update position.

Record the species: Right click on the species and click 'Add point'. In the 'Attributes – Point' dialogue box, click on the species pull down list. Type the first two/three letters of the species name to get to the section of the species list where your species name can be found. Do this quickly. Scroll through the list and select your species name. Ensure that the genus and family name are correct. Click 'OK'. Do this for every new species you see in the video.

For species that cannot be identified during analysis, take a still from the video, if the visibility is good enough and the animal's features can be seen clearly in a still image. Otherwise, make a video clip of the species (using VLC). Compare the image or clip against the identification guides available (e.g. Branch et al. 2022). If the species still cannot be identified, approach local and regional experts (e.g. academics specialised in the taxon in question) to request their assistance.

Recording MaxN values: Once a new (for that video sample) species of marine fauna has been observed in the sample, watch for later frames where more than one individual of that species are present. In any later frame where a greater number of individuals occurs, all of those individuals should be marked in EventMeasure. In this way, the highest number of individuals of that species that are observable in a single frame will be recorded by the software. This will be the MaxN for that species, for this sample.

Ending the period 'Analysis': after a full 60 minutes of analysing, find the 60.000 mins frame by using your RIGHT/LEFT keys. Set the end of the 'Analysis' period.

**Generating MaxN**

MaxN is the maximum number of individuals of a species in any one frame for the duration of video footage. The MaxN metric eliminates pseudo-replication caused by individuals swimming in and out of the camera's field of view (Willis et al. 2003). MaxN can be found by clicking on data view and switching from Points to MaxN view. To export MaxN values, produce a text report for each EMOB you've generated and store them in the 'Data → Raw data → Text reports' directory. Combine the text reports for each data type into a unified text file. Subsequently, find the folder containing your text files. Open a text file by double-clicking on it. Copy and paste the data from this file into a new worksheet in Microsoft Excel, then rename the worksheet to correspond with the data type (e.g. 'MaxN by period').

**Length measurements**

To accurately measure the fish, you must locate a frame where the full body of the fish is clearly visible in both the left and right video feeds. If the fish is only visible in one camera throughout the footage, you will not be able to obtain accurate measurements. Once the fish is visible in both cameras, align the fish's body until it is as parallel to the camera lenses as possible by moving through the footage frame-by-frame. A clear view of both the top lip and the caudal fork is necessary for it to be measured. Begin by focusing on the left camera: zoom in to capture the fish's snout and mark its top lip with a left click. Then, zoom out and refocus on the tail, marking the caudal fork. Repeat this process with the right camera. An Attributes and 3D Information dialogue should appear automatically, if it does not, right-click and select 'Add length measurement'.

**Measuring visibility**

Scroll through the hour-long video to locate a frame where you can clearly identify the species furthest from the camera. Utilise the zoom function to click on the fish's eye in both the left and right camera views. This action should result in a 3D point information dialogue box appearing. Assess whether the displayed range seems right and if so, input the range value (####.###) into the designated information fields. To do this, go to 'Measurement', select 'Information field values', double-click on the visibility box and input the number. Omit the 'mm' unit when entering the value.

If the value does not seem correct given the position of the fish relative to the BRUVs, try the same process again with another fish or a static, identifiable point on the seafloor.

**Temperature data**

Download the temperature data from each logger at the end of the field season (or the end of several days of fieldwork, if there are likely to be long breaks in the fieldwork). Match up each deployment of the BRUVs with the corresponding section of temperature logger data. Crop the corresponding 60-minute segment of data for each deployment, paste it into a new file and rename the file using the BRUVs sample number. Allow a 1 to 2 minute delay for the temperature logger from the time the system reaches the seafloor. Calculate the median or mean temperature from the remaining data points that corresponds to the recording period, and use that value as the temperature value for the BRUVs sample.

**Troubleshooting: Analysis**

***Calculating visibility***

Problem: Some samples will not contain a fish passing at the furthest point of visibility, from which a visibility estimate can be calculated.
Solution: Another object such as an identifiable rock or benthic organism, can be used, as long as it is visible on both cameras. The visibility can also be calculated from footage as the camera is being lowered or lifted, while it is still close to the sea floor, again using an identifiable feature at the furthest extent of the visible field.

Problem: The visibility changes considerably over the course of the sample, making it difficult to know what measure of visibility to use.
Solution: Calculate an average visibility, based on a middle-point between the best and worst visibilities. Or, if there is only poor visibility for a short period during the video, use a value that represents visibility for the majority of the sample. Most importantly, be consistent in how you deal with these issues across the whole dataset.

***BRUVs flipped over during deployment or landed upside down***

Problem: An upside-down BRUVs may still record useful footage, but depending on the angle it lands at, it may provide a limited view of the water column. This restricts the area within which marine fauna can be detected by the analyst.
Solution: A '% water column' value is calculated for every video and entered into the 'Information field values'. This provides an estimate of the field of view (FOV) and can be used to weight MaxN values accordingly.
If the BRUVs inverts during the course of a video sample, an average field of view can be calculated based on the FOV before and after inversion.

***BRUVs moving during analysis - because of swell or strong current***

Problem: If the BRUVs legs are dragging along the seafloor, or if the BRUVs is lifted by swell or waves, and then dropped back down onto the seafloor repeatedly, the habitat/ benthos may be damaged. Depending on the seabed type, each time the BRUVs lands back on the seafloor, a plume of sediment might be created, which temporarily reduces visibility. Any dragging or significant displacement of the unit means that the sample is not taken from one fixed place, and if the unit moves a lot during the deployment it may end up sampling a very different area (and possibly even seabed type) from the one at the start of the sample.
Solution: The solution will depend on the severity of the situation. The sample may be unusable if the movement has deterred all fish species (although the sample can still be used to describe the seafloor type at the point of deployment). If the seabed type or visibility do not change during the

course of the sample, but the system is clearly moving, there is still the chance that at least some species will have been deterred. The samples should be analysed but the resulting data should be noted as potentially compromised, as some species may be recorded but others typical of the depth/habitat/season/region may not be present. The sample may have to be excluded from final analyses.

***A 'chop' or other synchronisation point was not made prior to deployment of the stereo-BRUV.***
Problem: A synchronisation point is required in order to synchronise the footage from the left and right cameras. This is essential if fish lengths are to be measured.
Solution: Identical frames can be found in both the right and left footage. For instance, the moment when the bait canister makes initial contact with the water can often serve as a reference point for synchronising your videos.

## 3. MONO-BRUVS

### 3.1 INTRODUCTION

Mono-BRUVs are simpler versions of stereo-BRUVs, with just one camera and usually a smaller frame. They can be cheaper to build and use (they do not require specialist software like EventMeasure for analysis and free software such as VLC can be used to review videos), are lighter to handle and the resulting data are simpler to analyse and require only half the storage space. They have been suggested as a possible alternative to stereo-BRUVs, for monitoring marine fauna in the NIMPA, if funding or personnel for data analysis are limited (Leeney 2024). Mono-BRUVs still provide diversity information, a measure of abundance and information on seabed and habitat types, but unlike stereo-BRUVs, they cannot provide data on fish lengths.

Smaller mono-BRUVs remove, in most cases, the need for a winch on the research vessel, although the retrieval process still becomes challenging in deeper waters. In South Africa, monitoring recommendations in several MPAs have suggested a rotational cycle approach to monitoring in collaboration with other entities, i.e. annual mono-BRUVs sampling by MPA staff, and stereo-surveys every 5 years, sharing the stereo-BRUVs equipment with other MPA teams. This can usually meet MPA monitoring objectives because declines in populations of target species can occur rapidly, and would be detected even with mono-BRUVs, whilst population recoveries (which might be first picked up through increases in size of target species, or an increasing diversity of size classes over time) occur slowly and thus detection of changes in fish size would not be required on an annual basis.

The processes for setting up, deploying and retrieving mono-BRUVs and dealing with the resulting data are very similar to those previously described for stereo-BRUVs. There are standardised measures that should be kept consistent throughout the BRUVs methodology, from fieldwork to analysis, that will facilitate regional and ocean basin comparisons over time. However, the BRUVs method should also be adapted to work (logistically, financially and practically) in the specific region or context of interest. A document providing guidance specifically for the use of mono-BRUVs is available on request from the authors (de Vos 2014).

A mono-BRUVs frame with a light mounted on the top.
©Tamsyn Livingston, Ezemvelo KZN Wildlife.

## 3.2 FIELDWORK

### Equipment

The materials required to construct a mono-BRUV system are not listed here, as there are several different designs for mono-BRUVs. If mono-BRUVs are incorporated into future monitoring plans for marine ecosystems in Namibia, it is recommended that the monitoring team contacts researchers in South Africa who are using mono-BRUVs, to request information regarding the design and specifications of the system(s) they use.
Refer to NNF safety documents for all required safety equipment that should be present on the research vessel for every trip. All team members working at sea should wear a lifejacket.

### Deploying and retrieving mono-BRUVs

The process of deploying and retrieving mono-BRUVs is similar to that for stereo-BRUVs, except that there is only one camera to set up for each system, and thus only one camera/ system name and memory card number to record on the datasheet, for each deployment.

## 3.3 DATA MANAGEMENT

The same system described for stereo-BRUVs data management should be used for mono-BRUVs data. The only difference is that there is no need for separate folders for left and right camera files, and there will also be no need for a folder for camera calibration files.

## 3.4 ANALYSIS

Since data from mono-BRUVs do not allow for fish lengths to be measured, there is no calibration process required and the use of specialised analysis software (primarily EventMeasure) is not necessary. Mono-BRUVs data can be analysed using the free video viewing software VLC Media Player, or alternatively using ADOBE Premier Pro (paid subscription), and the data entered into Excel. However, EventMeasure does allow the analyst to stitch together the multiple short files that a GoPro records during a 60-minute recording, making analysis simpler.

The rest of the analysis process for mono-BRUVs data is broadly the same as for stereo-BRUVs data, although the process will be slightly different if EventMeasure software is not being used.

- Open the video file and play the video until the mono-BRUVs lands on the seafloor. Allow the system and any disturbed sediment to settle, then record ‘time on seafloor’, which marks the start of the 60-minute analysis period.
- Record the video duration, visibility (if not using EventMeasure this can be done using a basic scale of good, medium or poor), bottom type (select from the standardised list: *a) Sand, (b) Patch-reef high, (c) Patch-reef low, (d) Reef high, (e) Reef low, (f) Sand inundated reef, (g) Mud, (h) Kelp forest, (i) Seaweed garden*), %water column, % obstruction.
- Extract a survey area image and habitat image and save it in the folder ‘5_Environmental data’.
- Begin analysis - watch the footage for 60 minutes.
- Any visible marine fauna should be noted, along with the time they first appear and the number of individuals in the frame. Record the maximum number of individuals of each species as the MaxN value for that species, and the time at which MaxN occurs. This will become your measure of relative abundance for each species.

## 4. DATA INTERPRETATION

BRUVs and the data they generate can contribute significantly to inform the management of marine ecosystems and species. Effective management of the marine environment and marine biodiversity requires an understanding of the ecology of key species (usually fishes) and how they change over time. Management must therefore be underpinned by ongoing research and monitoring (Harvey et al. 2021). The design of spatially-explicit management approaches (e.g. areas closed to fishing, areas with fishing gear restrictions or areas where no recreational activities are allowed) for species of conservation or management interest, requires spatially extensive data on species distribution and the environmental variables that likely influence patterns in species abundance and diversity.

**Relative abundance**

The basic output from the video sample resulting from each mono-BRUVs or stereo-BRUVs deployment is a series of MaxN values. MaxN represents the maximum number of individuals for each species visible at one particular time (i.e. in a single frame of the video sample). It accounts for the fact that in a one-hour video sample, many of the same individuals of a species may appear in the footage multiple times. MaxN values for each species identified in the sample can then be compared with those from other samples, allowing comparison amongst multiple sites and across years.

**Fish lengths**

Using stereo-BRUVs to make precise linear measurements of fish has become widespread. When length measurements are precise, length-weight relationships obtained from published studies can be combined with relative count data (MaxN) to convert size data to biomass estimates (Johansson et al. 2008), which is especially useful for assessing the status of populations of species of interest. Size data also provide insight into which life stages (e.g. neonates, juvenile, sexually mature adults) of species of interest are found in the different areas monitored with stereo-BRUVs. For these reasons, the use of stereo-BRUVs has been recommended for longer-term monitoring of chondrichthyans in the NIMPA (Leeney 2024).

Measuring even just a subset of the species that are recorded by stereo-BRUVs monitoring requires additional staff time and expertise, however. This may not be feasible for MPA monitoring teams in Namibia. In South Africa, monitoring recommendations in several MPAs have suggested a rotational cycle approach to monitoring in collaboration with other entities, i.e. annual mono-BRUVs sampling by MPA staff, and stereo-surveys every 5 years, sharing the stereo-BRUVs equipment with other MPA teams. If additional MPAs are designated in Namibia, this rotational approach may work well, but having sufficient staff with experience in measuring fish lengths from stereo-BRUVs datasets will be essential to ensure the proper analysis and interpretation of data resulting from stereo-BRUVs surveys.

## 5. CLOSING A FIELD SEASON

At the end of each field season, it is important to clean and properly store all field equipment. This is also a good time to check the condition of the equipment, make note of any damage or required equipment, and ensure that it can be repaired or replacements bought before the next field season. The main tasks are:

- Ensure temperature loggers are switched to sleep mode.
- Rinse down all BRUVs frames with freshwater and allow them to dry. Store them somewhere where they will not be repeatedly moved or damaged and ensure they do not have other heavy equipment/ items stored on top of them, which may cause them to become misshapen. Ensure the camera housings are dry and closed. It is recommended to place silica sachets in all housings during storage to prevent any moisture retention.
- Rinse all surface buoys, ropes and rope boxes. Deflate the surface buoys for easier storage. Once dry, store the ropes in the clean rope boxes. If ropes have been cut to different lengths to suit different deployment depths, it is helpful to label each length of rope accordingly and ensure, at the end of each field season, that those labels remain legible.
- Charge all BRUVs batteries and light batteries fully before packing them away.
- All electronics (chargers, batteries and the GoPro cameras) should be stored securely (ideally in a clean, dry pelican case) in a dry place where they will not be exposed to extreme heat or cold.
- Clean out the toolbox, clean all tools to prevent rusting and make note of any replacements needed.
- Wash the gloves well with soap and water and allow them to dry fully before storing.
- Ensure everything is clearly labelled to avoid equipment going missing. An equipment inventory is advisable.

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## APPENDIX I: Equipment Checklist - Stereo-BRUVs calibration

Stereo-BRUVs frames
Go-Pro cameras (fully charged the night before)
Bucket/ other object at least 50 - 70 cm in height (on which to place the stereo-BRUVs in the pool - must be an object that will sink)
Calibration cube and distance bar (source: SeaGIS)
CAL software (source: SeaGIS)
Datasheets for recording of data on calibration recordings
Pencil and eraser

## APPENDIX II: Equipment Checklist - for each trip to sea

For stereo-BRUVs work:
Stereo-BRUVs frames (3 stereo-BRUVs is the ideal number for maximising efficient data collection)
Bait arms and canisters
BRUVs legs

For mono-BRUVs work:
Mono-BRUVs frames
Bait arm and bait canister, if they are detachable
Additional materials may be required depending on the system design (e.g. a simple mild steel mono-BRUVs rig requires that the GoPro be attached using a handlebar mount)

For all BRUVs fieldwork:
Floating ropes (a range of lengths; Dyneema rope is recommended)
Surface floats (buoys)
GoPro video cameras (enough for all BRUVs plus at least one spare camera)
GoPro batteries and memory cards[1]
Camera housings
Bait and cooler box
A large, strong plastic bucket and large stick for crushing bait
Weights (to attach to BRUVs frame when working in high current conditions)
Several copies of the field data sheet (Appendix IV) and clipboard
Pencil, eraser, pencil sharpener
Light batteries (two batteries per BRUVs plus two spare batteries)
Silica crystals and silicone grease
Toolbox (see contents below)
Spare GoPro housing
Life jackets[2]

[1] An unused (that day), fully charged battery and unused (that day) memory card are required for each BRUVs deployment, so the team must bring enough to facilitate all the deployments planned for the day, plus several spare batteries and memory cards in case of failures. So if 12 BRUVs deployments are planned, the team should carry at least 15 batteries and 15 memory cards.

[2] Life jackets should be the low-profile, inflatable type. The $CO_2$ cylinder should be checked for corrosion and tightness at least every three months, as these cylinders may become loose and fail to operate and corrosion may cause the cylinder to leak. At least every six months, all lifejackets should be inflated orally or by hand pump to avoid moisture build up inside the jacket, and left inflated for 24 hours to ensure they hold their pressure and to see if there are any leaks or damage. If life jackets are not in use for several months, they should be stored in a dry place, partially inflated, and hung from a non-metal hanger.

Gloves with rubberised palms (for hauling BRUVs)
Fully charged cellphone with plenty of call time (credit)
A handheld GPS with batteries

A copy of all necessary permits for conducting BRUVs research

Optional: temperature loggers (e.g. bluetooth enabled HOBO TidbiT MX Temperature 5000' Data Logger); one attached to each BRUVs frame

Each crew member should also bring water, lunch, snacks, a waterproof jacket, sunglasses, a hat and sunscreen, as well as any personal medication (even if not required during the anticipated period of work at sea) and sea sickness tablets, if needed.

**The toolbox should contain:**
Size 8 and 10 spanners
Pliers
Allen key multi-tool set
Screwdriver multi-tool set
Silicone grease
Duct tape, cable ties (large and small sizes)
Rags and 2 clean cloths
Spare coil of wire (for attaching bait canister to bait arm and other minor repairs)
Ideally contained in a sealable, waterproof case such as a small Pelican case

For all fieldwork conducted at sea, also consult the Safety At Sea Protocol developed by the NaRaS team and ensure that the relevant safety equipment (listed under 'Required boat safety equipment') is brought for each trip to sea.

## APPENDIX III: Additional equipment to take on a fieldwork trip, which remains in the office

GoPro camera chargers
Light battery charging cables
Card readers for camera memory cards
At least one laptop to enable video files to be downloaded and viewed (i.e. with VLC media player installed)
Two external hard drives with adequate memory for the trip's video files (to allow all BRUVs video samples to be saved and backed up)
EventMeasure USB key (if analysis is to be done during the field trip; source: SeaGIS)
Calibration USB key (for the analysis of the calibration files)

## APPENDIX IV: Field data sheet

| | | | | |
|---|---|---|---|---|
| Date: | Fieldtrip code: | Project code: | Location: | Notes (surface conditions/ incidents etc.) |
| Wind sp (kn): | Wind dir: | Cloud cover: % | Rain (y/n): | |

| Sample code | Site | Cameras | | Cards | | Bait type | Bottom depth (m) | Current (kn) | Time in | Time out | In - Lat | In - Long | Out - Lat | Out - Long | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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