Marine Biodiversity Hub

National Environmental Science Programme

7. MARINE SAMPLING FIELD MANUAL FOR TOWED UNDERWATER CAMERA SYSTEMS

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Left image courtesy of the Marine National Facility. Right image courtesy of the Australian Institute of Marine Science

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7.1 Platform Description

Towed underwater camera systems, of various configurations, have been used since the turn of the 20th century to acquire video and photographic still images of the seafloor (Bicknell et al. 2016) They are deployed on a cable from a surface vessel, have no propulsion mechanisms, and generally have forward-looking oblique and/or downward-looking cameras that either record images which are stored and subsequently downloaded, or transmit data directly to the surface in real-time via a coaxial or fibre optic cable (Bowden and Jones 2016, Durden et al. 2016a). Towed underwater cameras not only augment data from collected specimens (Chapter 8, 9); they also provide an important non-invasive sampling alternative where extractive methods are either unnecessary or unsuitable, such as in sensitive deep-sea habitats (e.g. Althaus et al. 2009, Williams et al. 2015, Sherlock et al. 2016), or for repeated sampling in marine reserves (e.g. Lawrence et al. 2015). Towed platforms also have the added advantage of providing cost-effective permanent data capture along transects that can be up to several kilometers in length and can be used to traverse highly heterogeneous seafloor topography (Shortis et al. 2007, Sheehan et al. 2016). The quality of imagery acquired by towed systems depends largely on sea conditions and water clarity, both of which may vary considerably depending on geographic location, season of sampling and extent of tidal influence. In depths greater than around 30 m, lighting and camera specifications become increasingly important to image quality. The quality and versatility of equipment and the maintenance of a consistent flying altitude above the seabed are also critical factors affecting image quality and usability.

Conventional underwater still photography and video imagery were initially applied by marine ecologists to collect basic qualitative data (e.g. simple visual assessment of seabed conditions to assess habitat type or dominant species), or often low-accuracy quantitative data estimated through the use of parallel lasers to define the scale of the images (see Harvey et al. 2002, Shortis et al. 2008, Durden et al. 2016a). Recent technological advancements have emerged that permit collection of high-resolution benthic imagery using versatile multifunctional towed platforms carrying a variety of camera systems (e.g. stereo-image measurement systems) and a range of other sensors (e.g. high-resolution multibeam and side-scan sonars, motion sensors, conductivity temperature and depth sensors, and subsea acoustic positioning systems) (Kocak et al., 2008, Rattray et al. 2014, Bowden and Jones 2016, Durden et al. 2016a, Logan et al. 2017). This technology, coupled with advances in camera resolution, positional accuracy, digital data processing and visualisation techniques, has enabled more quantitative and spatially-referenced studies of the seafloor. Calibrated stereo-imaging in particular has facilitated more reliable length measurements of mobile species, such as epibenthic invertebrates and demersal fish, and more accurate estimates of biomass and population distributions (Harvey et al. 2002, Shortis et al. 2009). Towed underwater imaging systems can be applied to acquire baseline data, evaluate benthic diversity, map benthic habitats, identify vulnerable communities, assess changes in biota, and support spatial and ecological modelling/monitoring.

7.2 Scope

As still and video cameras can be mounted to tow bodies in a variety of ways (Figure 7.2, Table 7.1), this field manual does not mandate specific gear types. Rather, it provides recommendations for future updates or replacement of existing platforms. It targets the suite of towed camera platforms currently being used to acquire quantitative imagery of benthic habitats in Australian waters, and seeks to standardise monitoring efforts by recommending standard operating procedures (SOPs) for survey planning, field acquisition and post-survey data processing, description, and storage for public accessibility (Figure 7.1). The primary aim of this field manual is to establish a consistent approach to marine benthic sampling using towed camera systems which will facilitate statistically sound compilation between studies. Note that hybrid towed systems and other video-based monitoring platforms (e.g. dropped video cameras, or video and still cameras mounted on sleds or trawls) that are commonly used to gather qualitative sample data (e.g. general animal behaviour) fall outside the scope of this manual.

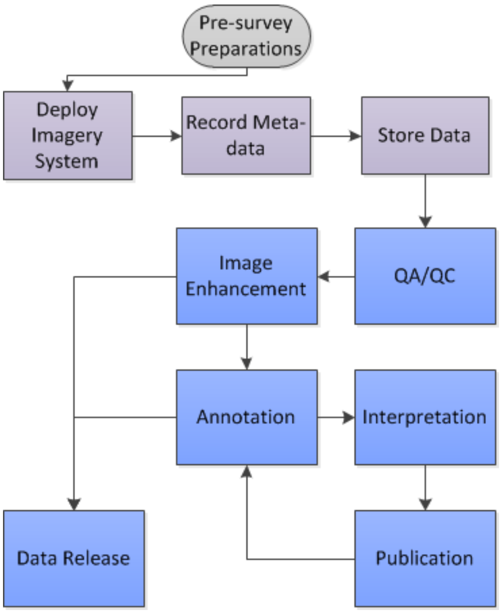

Figure 7.1: Workflow for towed camera image acquisition and processing. Purple represents onboard methods, while blue represents post-survey methods.

7.3 Towed Underwater Cameras in Marine Monitoring

Standardised methods of survey design, data collection, analysis and reporting are essential to monitoring both the status and change in Australia's vast benthic marine environment. Efficient management of a given area requires first establishing a baseline of the key biota, and then regularly monitoring their status to detect changes over time. Changes to the diversity and abundance of benthic organisms and communities are commonly used ecological metrics in marine imagery because epibenthos is considered to be functionally important and sensitive to human activities (Williams et al. 2015). Although repeated presence-absence surveys for occupancy estimation or changes in benthic community composition can be achieved using towed camera systems, returning to a precise geographical location for a particular monitoring purpose (e.g. Bridge et al. 2014, Ferrari et al. 2016, Pizarro et al. 2017) requires an alternate sampling platform entirely (e.g. AUV in Chapter 4). However, despite known biases and limitations (e.g. Jones et al. 2009, Katsanevakis et al. 2012, Durden et al. 2016a, Durden et al. 2016b), towed camera systems are anticipated to play an important role in future monitoring strategies, and have been identified as one of the sampling methods capable of monitoring the indicators associated with shelf reef systems (Hayes et al. 2015).

The application of towed underwater camera systems to environmental monitoring involves several key steps. These include survey design (Chapter 2), pre-survey preparations, field implementation (e.g. image acquisition and onboard data storage and description), and post-survey procedures (e.g. processing of imagery for data extraction, image annotation, statistical analyses of extracted data and data release). A brief overview of these fundamental steps is provided below.

7.4 Pre-Survey Preparations

Ensure all permits, safety plans and approvals have been obtained. Any research undertaken within AMPs requires a research permit issued from Parks Australia. See Appendix B for a list of potential permits that may be required.

Confirm sampling design meets survey objectives, is achievable with planned equipment and time, and has been communicated to all key scientists and managers. Generally, the sampling design in an ecological study should be statistically sound with adequate spatial coverage and replication, and it should use an explicit randomization procedure to ensure that independent replicates are obtained (Durden et al. 2016a). Increasing sample size where possible will also help to better inform models, and increase the study's robustness (Mitchell et al. 2017). See Chapter 2 for further details on sampling design.

Define the sampling area to be surveyed in terms of space and time and identify any categorical constraints that may need to be imposed (e.g. acceptance of only those images captured within an altitude range of 2–4 m above the seabed) (Durden et al. 2016a).

Determine sampling unit (what to quantify within an image) and sample size (number of images, number of transects) to sample the habitat of interest. A complication in the determination of sample size in image-based studies using towed camera systems is variability in the physical size represented by respective images as the camera-to-subject distance often varies (Durden et al. 2016a).

Determine appropriate imagery system based on metric to be quantified. For seafloor imagery, some of the most important operational factors for the design of a platform and its deployment are depth, bottom topography, duration and spatial extent of survey, current speed, altitude control, turbidity and surface sea conditions (Barker et al. 1999). The specific configuration of equipment will depend on the scientific objectives of the survey and the type of data required. For example, high-definition video is commonly used to assess the spatial distribution, abundance and behaviour of benthic epifauna, and is also well-suited to identifying the spatial extent of substratum types and biological habitats (Bowden and Jones 2016). High-resolution images from stereo-cameras on the other hand are necessary for detailed species identification and precise sizing of individual organisms and quantifying specific seabed features (see Dunlop et al. 2015, Durden et al. 2016a, Sheehan et al. 2016).

Determine appropriate camera orientation. Camera orientation for towed systems is a critical parameter for quantitative interpretation of imagery (Bowden and Jones 2016). Images captured perpendicular (i.e. downward-facing) to the seabed are commonly used for spatial benthic ecological studies of sessile organisms, and substratum or seabed composition (Durden et al. 2016a). Whereas, images captured at oblique angles tend to be used for studies of motile fauna, such as demersal fish, as the image frame captures a greater area of seabed (or a larger volume of the water column) (see Bowden and Jones 2016, Durden et al. 2016a). Oblique camera orientation typically introduces inherent gradients of both lens-to-subject distance and illumination intensity, while a vertical orientation generally provides more even illumination and uniform subject-to-camera distance (Bowden and Jones 2016). These properties make vertical (i.e. downward-facing) orientated images more optimal for quantitative analyses of benthic substrata and sessile or sedentary biota . We recommend combining high-definition oblique video with high-resolution downward-facing camera/s, as this makes full use of both the descriptive potential of oblique-facing video (N.B, stereo-video required for examining fish metrics) and the potential for accurate quantitative analyses from vertical images, as well as reducing the risk of collision with seabed obstacles (Bowden and Jones 2016). Downward-facing camera/s, coupled with accurate geographic positioning (e.g. USBL, motion sensor) can facilitate mosaicking of images similar to that achievable with AUV platforms.

Particular care should be taken when selecting platform and optics, especially when developing a long-term ecological monitoring program. For example, it is not recommended to change the gear specifications over the monitoring period if the purpose of the study is to detect change over space and time (Sheehan et al. 2016).

Ensure accurate geo-referencing (position, position, position!). The geographic position and orientation of the camera(s) at the time of image capture is *critical* for ensuring accurate geo-referencing of an image (and the objects within it). This geographic position must be integrated with other sensor data to develop habitat maps or interpolations (see below). It is also critical for relating the sampled area to environmental co-variates extracted from hydro-acoustic (Mitchell et al. 2017) and other platform sensors (Shortis et al. 2007).

Ensure synchronisation of time stamps. The time standard (typically UTC) for a given survey needs to be pre-determined and strictly adhered to. Synchronisation of time stamps across all systems (e.g. USBL and other platform sensors, PC time(s), ship navigation, video and still camera systems) is *critical* for ensuring accurate geo-referencing of images. Time accuracy to three decimal places is optimal.

Determine real-time annotation protocols, if desired. Although real-time annotation is not required for this field manual, it is recognised that this is an established practice for many individuals and agencies. If a real-time imagery feed is available, follow agency-specific protocols for onboard annotation. At the least, a qualitative description can be written for each station, thus ensuring some information is immediately available for post-survey reporting and to guide subsequent analysis (see Appendix C) *[Recommended]*.

Stereo-cameras should be pre- or post-calibrated in shallow water using the techniques outlined in Shortis and Harvey (2009). Typical requirements of a multi-station, self-calibration network include multiple convergent photographs, camera roll at each location and a 3D target array (see Shortis et al. 2009). If housings or mounts are changed or damaged during deployment, re-calibraton is required.

Paired calibrated lasers should be used if not using stereo-cameras, with a known separation distance used as a reference for scaling objects. This can enhance the performance of 2-D and 3-D imaging systems/reconstructions (Caimi et al. 2008) and align video and stills by time.

Consider potential spatial and temporal errors that may result from the choice of towed camera system and how these errors may potentially affect habitat mapping and modelling of data (e.g. Monk et al. 2012, Rattray et al. 2014). It is important to take into account errors from vessel motion (i.e. heave, pitch, roll and yaw), USBL beacon positioning, GPS, and measurement inaccuracies resulting from the application of stereo-camera calibrations carried out in shallow water to imagery gathered at greater depths (see Shortis et al. 2009). It is also important to ensure that the recording frequency of sensor data is matched to the intended use of the sensor data – e.g. pitch recorded at 1s intervals may not be sufficient to correct for changes in the field of view in a video as the camera is towed.

Consider locational uncertainty in occurrence data. To generate realistic predictions, species distribution models require accurate geo-referencing of occurrence data with environmental variables (Mitchell et al. 2017). Although some high-performing, fine-scale models can be generated from data containing locational uncertainty, interpreting their predictions can be misleading if the predictions are interpreted at scales similar to the spatial errors (Mitchell et al. 2017). See Foster et al. (2012) and Stoklasa et al. (2015) for a more statistical view of this issue in an ecological context.

Consider onboard data formats and establish workflow for data transfer and battery charging prior to survey commencement. This field manual does not mandate particular data formats as these may differ depending on the choice of annotation software and process for specific extensions. For example, video data may require transcoding into web-viewable format (e.g. H264). Common formats include .mp4 and .avi for video data and .jpeg, and .tiff for still imagery. Several video containers (e.g. Quicktime) allow embedding of timecode and/or closed caption tracks into the video file and are frame-accurate during playback. Where possible such formats are preferable. The H264 codec is suboptimal for high speed transects so original video file copies should be kept for reference during analysis. In some instances, saving information in raw format may be necessary for the purpose of post-processing. Files may also need to be compressed for public accessibility. Regardless of data formats, it is essential to establish a workflow for data transfer and battery charging prior to survey commencement.

Consider the metadata required for subsequent data post processing, storage and release, such as the video or image location, camera attributes, date, time, altitude, angle of acceptance, motion of towed platform (i.e. heave, pitch, roll and yaw) and the precision required of each (Durden et al. 2016a). Consider size, location and access of final imagery and video datasets and where these will be archived. Metadata must be adequate enough to satisfy conformance checks for data release via open access data portals such as the Australian Ocean Data Network (AODN http://imos.org.au/facilities/aodn/aodn-submit-data/).

Consider how metadata will link to media type. The most effective way to link visual imagery with metadata is by incorporation into a spatially enabled relational database (Bowden and Jones 2016), using the synchronised time stamps and GIS position for linking imagery and sensor data. Important considerations include:

- Archived filenames should include Platform, Date and Start-Time (PlatformYYYYMMDDHHMMSStextstring)
- If possible we recommend writing image metadata into EXIF fields embedded in the digital image file to ensure metadata is not separated from images
- Geotagging video imagery is less established but various options exist including: i) Embedding position, date and time on the imagery itself suggest using an inconspicuous location within the field of view; ii) Utilizing the video audio track or closed-caption track to record position date and time using a geostamping device, iii) Proprietary video recording and playback equipment and /or software that associates position metadata with recorded video files (e.g. Streampix https://www.norpix.com/products/streampix/modules/gps.php; GeoDVR https://www.remotegeo.com/mission/marine/subsea-rover); and iv) Embedding UTC timecode into the video media file (e.g. Quicktime .imov files recorded by AJA KiPro devices can have timecode generated and embedded by a GPS-timecode generator)

7.5 Field Procedures

The steps below are comprehensive for the entire workflow of towed camera systems. In many cases, there will be a designated specialist or team to perform some of these steps. Indeed, for heavy Deep-Tow and complex systems (e.g. JAMSTEC's deep-tow systems), most, if not all of these steps may be managed by external technicians and engineers. In this case, it is the researcher's responsibility to ensure that the externally managed workflow is comprehensive and addresses the steps as described in this field manual. This is best done in Pre-Survey Preparations.

7.5.1 Pre-deployment

Risk Assessment

Complete an on-site Workplace Health and Safety risk assessment following agency-specific protocols. A risk assessment should always be completed prior to deploying equipment to ensure the operation can be completed safely. Always adopt a precautionary approach.

Set up and testing

Allow sufficient time during survey mobilisation to undertake system checks, calibrations and testing of equipment and account for unforeseen problems. In most cases it will be possible to complete all system tests and checks within a few hours to half a day. The conduct of pre-start checks should be noted in the trip log and any test failures specifically recorded for later-reference. Detailed settings for each component should be made using relevant operations manuals (e.g. USBL operations manual etc.).

On-deck dry tests should include, but are not limited to, the following checks:

- On-board storage;
- On-board power;
- Cameras, including a review of image quality (colour chart test);
- Lights and strobes;
- Seals/o-rings;
- Recording devices;
- File copy times for offline recording devices (e.g. GoPro);
- Winch operation;
- Sea fastening;
- Surface communications; and
- X-Y-Z co-ordinates from the tether termination to the imaging chip of each camera, altimeter, depth sensor/CTD and transponder.

Wet testing should include checks of the following:

- Power;
- Cameras, including a review of image quality;
- Acoustic tracking system (USBL) and any internal navigation; and
- Lighting and strobes.

Acoustic tracking setup

- Set position of GPS receiver. Differential GPS is recommended as a minimum and is mandatory for repeat site monitoring.
- Deploy acoustic tracking transceiver (e.g. pole, flange or vessel mounted).
- Measure offsets of USBL transceiver head to GPS receiver and put offsets into navigation system.

- Ensure accurate vessel dimensions are obtained and entered into the vessel plan repository of the navigation software.

<u>Stills camera time calibration</u>

- Calibrate the stills camera and video feed from GPS in the video overlay relative to UTC time
- Ensure all sensor logging systems, cameras, computers have been synchronised to UTC time
- Time coding calibration should be applied at the commencement of a survey and checked for consistency at least once a day while the survey is in progress
- Ensure recording media/storage device is working correctly and review imagery/video

Pre-deployment checks

1. Ensure all personnel understand their roles by conducting an appropriate toolbox talk, incorporating risk assessment and appropriate PPE to be worn. See Chapter 1 for further information about risk assessments.

2. Confirm with vessel master that GPS tracks for the proposed deployments are accurate and the order of transect sampling is clearly communicated.

3. Discuss the desired target location and the feasibility of deploying at that location. Main items to take into account are:

   - Terrain. To minimise the risk of a deployment almost all tows will be conducted on either a flat or downward sloping seafloor. This will reduce the chance of the camera hooking up and allow for the platform to fly out into deeper water if there is a winch failure. Consider if there are any large ridges, boulders, drop-offs, etc. along the proposed tow route as with minimal forward vision, 10 m or less, there is not a large margin for avoidance.
   - Weather/sea state. When the camera is flying along the ocean floor, the ship will need to travel at ~ 0.5-1ms^{-1}. This can limit the manoeuvrability of the ship and depending on the direction of the prevailing wind and swell, is not always possible on a particular heading. As the sea-state and swell can affect the ships manoeuvrability when travelling at low speeds it is essential to regularly check the weather forecast to ensure the sea state is acceptable and the platform can be safely deployed and retrieved.
   - Depth. Be aware of the depth limitations of the towed body and the wire that the platform is deployed on.

4. The vessel Master must approve each deployment and communicate with crew prior to launch.

5. Prepare tow body on deck and ensure only essential personnel participate in its preparation and deployment.

6. Check for correct operation of cameras and lights (check explicitly for miss-timing between image capture and strobe firing) and winch including watertight seals, power requirements, hydraulic power and hoses, time synchronisation (PC, USBL, camera systems) and recording media.

7. If necessary, attach the USBL beacon to the frame and check that it is operational.

8. Perform laser alignments as per manufacturer's procedure.

9. Inspect the platform for any deterioration in cables and cable ties, ensure frame nuts and bolts are tight and all equipment mounts are secure.
10. Ensure all connection to pressure housings and equipment are tight and secure.
11. Ensure winch clutch or load relief mechanism is adjusted to the correct tension prior to initial deployment.
12. Once all instruments are confirmed working, handclap within an overlapping field of view of all cameras.
13. Inform the bridge and deck you are ready to deploy and wait for confirmation from the bridge that the ship is at deployment speed and is approaching the start of the survey line.
14. Ensure the nominated winch driver is in the operations room with a functional and fully charged winch remote control, set to the specified channel.

7.5.2 Deployment

1. Run the towed body termination through the large block on the centre of the A-Frame and make sure there are no twists in the wire.
2. Following the signal to deploy from the vessel Master, use the winch and A-Frame to lift and guide the tow body from the deck into the water as the vessel begins tracking towards the start of transect line.
3. Minimise the time taken from when the tow body is let out of reach, to when it is lowered in the water, so as to reduce potential swing and impact against the vessel.
4. Deploy the platform into the water.
5. Check for cable loops or problems at the surface while the tow body is being lowered into the water before losing sight of the platform below the waterline.
6. Once in the water, lower the camera to an appropriate depth where system can be checked, turn everything on, including the lasers, and check that all is functional.
7. Check the USBL is receiving and the ship and platform are indicated on the bathymetry overlay.
8. Confirm that the USBL data is being logged.
9. There are several factors that affect how much wire out is required for the towed camera system to reach a target depth. These include: vessel speed through the water, payout/haul in speed, and cable diameter, package drag and weight. Determine the appropriate wireout ratio specific to the vessel and its speed, noting that ocean currents can affect this ratio.
10. Continually monitor the descent rate at separate intervals, checking the ratio of wire out to depth. This can impact on when the platform will actually reach the required depth and the location this will be. If the ratio is too high, there is the possibility of not reaching the required depth before passing over the target area. If the ratio is too low, the platform will reach the required depth well before the target area. The platforms descent rate and estimate touchdown location needs to be continually monitored for a successful tow.

11. To mitigate any positional errors, it is important to carefully monitor the ship speed and deployment rate to an appropriate ratio. If having reached the seafloor too early, try to resist speeding up the ship. This will cause the platform to rise when speeding up and fall uncontrollably when slowing down again.

12. Continue descent to a pre-determined height above the seafloor (e.g. 2–3m) and try to maintain this height throughout the tow using the winch remote control. Note: hauling in cable onto the winch or paying out cable has an immediate effect on the camera platform height above the seafloor; however, the degree of change on height above bottom is in relation to the cable angle, which is determined by the ships speed and current.

13. Confirm still photos are being taken and video feeds are being recorded where possible (e.g. recording indicators, hard drive operating).

14. Confirm timecode being embedded is GPS-time accurate.

15. If employing real-time annotation, record the time and position of the camera on the seafloor (See Pre-Survey Preparations).

16. While maintaining a consistent flying altitude above the seabed, the co-pilot needs to continually check the camera feeds to ensure all footage is being recorded and anticipate the need to come up on the winch so as to avoid approaching obstacles and minimise the chance of a seabed hook-up, and review.

17. Monitor sea conditions during deployment to maintain safe working environment.

18. Consider aborting operations if sea conditions are marginal, visibility is poor or any fault develops that may interfere with the towed camera system operation.

7.5.3 Retrieval

1. Continue deployment until advised by the watch leader/chief scientist that enough footage has been recorded.

2. When the survey line is complete or if the transect is being aborted, advise Vessel Master of intention to retrieve the tow body.

3. When close to the surface ask the officer on watch to confirm the ship is on the best heading for retrieval and hand over operational control to the deck crew.

4. Watch for approach of tow body near surface ensuring only required personnel near open transom.

5. If possible, turn off lasers before reaching ocean surface and turn off lights just below sea level.

6. Use winch and A-Frame to guide tow body back onto deck with smooth winch and A-Frame control inputs.

7. Ensure crew grab hold of tow body as soon as safe to do so when the tow body leaves the water, so it can be guided safely away forward of the transom and lowered to the deck.

8. Once clear of the water, stop all recordings, and turn all cameras, sensors and power off.

9. Rinse towed platform frame and all camera/sensors with fresh water.
10. If attached, remove USBL beacon and recharge.
11. Check and rename video footage, still camera photos and log files and complete Metadata Information sheet.

7.5.4 Seabed hook-up procedures

Hook-up of the tow body is always a possibility with the ideal altitude for capturing quality still images close to the seabed. The following procedures should minimise the potential of a hook-up occurring and lower the potential of damage to the tow body or total loss:

1. Communication link between tow camera winch station and bridge should be maintained at all times (e.g. VHF or intercom).
2. Bridge should monitor video feed from tow body while undertaking tows
3. At first sign of a hook-up (e.g. video image stationary over seabed), ensure forward speed of vessel is backed off to reduce tensile load on cable.
4. With crew monitoring position of the cable and directing the Vessel Master with regard to the position of the cable, the vessel is to maneuverer back to a point directly over the hook-up point to see if the tow body can be freed.
5. Cable tension should be taken up by the winch to ensure no loose cable enters the vessel propellers.
6. If the initial retrieval attempt from overhead fails, various points of the compass should be tested by the vessel to pull the tow body off the seafloor, using only the winch to ensure enough cable remains.
7. If all options for retrieval have been exhausted the cable must be cut at the shortest possible point and the position recorded with GPS.
8. A substitute tow body and cable would need to be prepared for continuance of survey operations.

7.5.5 Operation completion

Prior to any vessel movement or engine start-up, operators should check the following:

- All equipment is clear of the water, including acoustic tracking equipment;
- All gear is safely stowed and powered down where appropriate;
- Any servicing that requires the vessel to be stationary is completed;
- When the towed camera team is satisfied it is OK for the vessel to move on, an "All Clear to Move" command should be given to Vessel Master; and
- Data collected from previous tows should be checked for integrity prior to deploying the towed system on further tows.

7.5.6 Onboard data processing and storage

Consider navigation, data logging, real-time quality control, and display. A range of specialized marine image annotation tools have been developed worldwide to facilitate real-time underwater image analysis (reviewed in Gomes-Pereira et al. 2016). These tools generally consist of a graphical user interface, with a video player or image browser that recognizes a specific time code or image code, allowing events to be logged in a time-stamped (and/or geo-referenced) manner . Examples include: Adelie, Customizable Observation Video imagE Record (COVER), Frame-Grabber, Ocean Floor Observation Protocol (OFOP), SeaScribe/Seatube, Video Annotation & Reference System (VARS), VideoNavigator, Jason Virtual Control Van (web browser logger on a ships network allowing for digitally logging comments and observations during capture), CampodLogger . These software packages integrate data associated with video collection, the simplest being the position coordinates of the video recording platform, with more advanced packages allowing the input and display of data from multiple sensors or multiple annotators via intranet or internet .

Name data files according to established conventions. File naming conventions are important for ensuring both efficient and effective management of field data and its integration into appropriate data management repositories. It is important to note that these conventions will differ among agencies and academic institutions. For example, CSIRO uses: Survey code_operation#_UTCTime(hhmmss) (potentially Date time: YYYYMMDD-hhmmss)

Ensure accurate recording of metadata. Metadata is a descriptive data source comprised of information that may be used to process the images or information therein (Durden et al. 2016a). While it is important to follow agency specific protocols for capturing metadata, it is also essential that metadata is of sufficient detail to satisfy conformance checks for subsequent data release via AODN (See Table 7.2 for sample metadata sheet). Metadata should also contain survey-specific information such as camera specifications and imagery file naming protocol, as well as product lineage. Minimum data for each image/frame capture should include *georeferenced information*, as well as any other related *sensor information* and (where appropriate) *real-time characterisation* details:

- Campaign (i.e. Survey identifier)
- Station/event number
- Platform
- Latitude and longitude (WGS 1984 in decimal degrees *[Recommended]*)
- Altitude
- Depth
- Time and date stamp
- Platform and/or vessel motion (roll, pitch, heave)
- Metadata from other sensor data (see example below, CSIRO data file headers)
- Precision details (e.g. type of navigation system used and its associated errors)
- Data provenance

Quality control. Once the towed camera transect is complete, it is good practise to download associated raw imagery and positional data. Imagery and associated position data should be checked to ensure no failures have occurred, including but not limited to the following:

- Mis-timing between image capture and strobes (i.e. dark/black imagery)
- Failure of camera/s
- Failure of positional logging

Backup data. This is necessary to ensure all data collected in the field are safely returned and securely backed-up at host facilities, prior to final quality control and public release. Onboard copies of data should be made as soon as practically possible following acquisition. It is recommended that all data be backed up on a RAID or a NAS that contains built-in storage redundancy in case of hard-drive failure. A duplicate copy of all data onto external hard drives or LTO tapes for transportation back to host facilities is *[Recommended]*.

7.6 Post-survey procedures

7.6.1 Data processing

Image/video post-processing, selection and annotation method and detail will depend on the objectives of the survey/project. If documented properly using adequate metadata, imagery can be analysed, processed and annotated in a number of different ways to achieve different purposes.

A general workflow for data processing methodology can be found in Williams et al. (2012a). If constructing photomosaics from imagery, key requirements for raw image processing and positional data are as follows:

- It is recommended that at least one of the stereo images is in colour and enhanced following similar procedures as outlined by Shortis and Harvey (2009) and Bryson et al. (2016).
- All stereo images should georectified following Williams et al. (2012b).
- Positional data should be post-processed using Simultaneous Localisation and Mapping (SLAM) as demonstrated in (Barkby et al. 2009) and (Palomer et al. 2013).

7.6.2 Annotation framework

Scoring of individual images can be done using a number of annotation software tools. Examples include, Transect measure, Coral Point Count, CoralNet and Squidle+. For national consistency Squidle+ is recommended as it allows for different approaches to subsample images, which appears to influence inferences from data, as well as stratified and random point count distribution on images. It also automatically imports the collected towed camera data once it is uploaded to the AODN making it ready for analysis, and has tools for exploring survey data as well as analyses. In addition, it supports multiple annotation schemes, and will provide consistency through translation between schemes, which is an important point that differentiates Squidle+.

There are two main approaches recommended for annotating georeferenced imagery from towed camera systems:

- Annotation of individual images/frame grabs (real-time or post-acquisition)
- Annotation of photomosaics

Annotation of individual images or photomosaics can be undertaken using two methods:

1. <u>Full assemblage scoring of imagery</u> across space and time. It is important to note that this is a time consuming process, requiring a lot of replicate images to be scored to enable sufficient power to detect biologically meaningful change as most morphospecies are < 10 % cover within images. This approach appears to be good for delineating bioregional and cross-shelf patterns at a morphospecies and CATAMI (Althaus et al. 2015) level (Monk et al. 2016, James et al. 2017). This approach would be effective in choosing an initial suite of indicators for national level monitoring and reporting.

   As a general guideline for full assemblage scoring, we recommend that 25 random points per image from at least 50 images per transect leg are a good starting point for recording most morphospecies present within images (based on Perkins et al. 2016). It is important to note that the properties of the organism themselves will also influence the number of points/images to score. Obviously morphospecies that are less abundant require more effort, but also the 'clumpiness' of species will affect the scoring effort needed (Perkins et al. 2016). Van Rein et al. (2011) and Perkins et al. (2016) suggest that, while a higher number of points per image can increase the detection rate of more organisms within an image, increasing the number of scored images using fewer points is likely have a similar (or greater) effect. Ideally, increasing both the number of images scored and the number of points scored within an image would result in greater power (Roelfsema et al. 2006), but preference is usually for increasing the number of images (Perkins et al. 2016). Unfortunately, the adoption of this approach is likely to result in substantial increases in processing time and thus cost.

2. Targeted scoring of indicators or proxies (such as grouping fine level morphospecies into broader level CATAMI classes). This approach has been shown to work very well at an indicator morphospecies level for detecting change at a regional level (Perkins et al. 2017) as well as for detecting invasive species trends (Perkins et al. 2015, Ling et al. 2016). More recently this approach has been extended to mobile species, such as fish (Seiler et al. 2012) and lobster (Bessell et al., unpublished data). Care needs to be taken if length data (using photogrammetry or structure from motion) is extracted from stereo pairs as Seiler et al.(2012) found precision can be poor for mobile species if camera separation is inadequate (see Boutros et al. 2015).

   Since this approach requires substantially less effort to score each image, more images (i.e. often all images) can be scored, thus increasing statistical power. The drawback is that a narrower understanding of the environment may result.

7.6.3 Data curation and quality control

Data quality control at both the collection and annotation stage is critical. Most importantly, the annotation schema needs to be consistent between studies. Where possible morphospecies and associated CATAMI parent classes should be used *[Recommended]*. Clearly, other annotation schemas are available and can be applied. Where an alternative schema is used to annotate towed camera imagery, it is most important that it can be mapped to CATAMI so that comparisons can be made with previous studies or between regions. Translations between schema can be readily applied within Squidle +. The quality control of all annotations undertaken by novice scorers should be assessed against an experienced analyst (e.g. using confusion matrices; see Figure 4.4 in Chapter 4). Logically, it is important to correct any discrepancies between annotators. This can be done by re-examining the images to ensure an agreement can be reached between annotators. Alternatively, if an agreement cannot be reached, then the miss-classified morphospecies could be potentially grouped into a higher level CATAMI class.

7.6.4 Data release

Squidle+ is a centralised online platform for standardised analysis and annotation of georeferenced imagery and video. Many national marine observing programs (for example IMOS through the Australian Ocean Data Network (AODN), or the Marine Geoscience Data System (MGDS) in the USA) routinely store imagery data online in an openly accessible location. Squidle + operates based on flexible distributed data storage facilities (ie imagery can be stored anywhere in an openly accessible online location) to reduce data duplication and inconsistencies, and provides a flexible annotation system with the capability to translate between different annotation schemes.

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

1. Create a metadata record describing the data collection. Provide as much detail as possible on the deployment (either directly in the metadata record itself, or in the form of attached field sheets as .csv, .txt or similar). Details of minimum metadata requirements are provided in On-board Data Storage section above. Publish metadata record(s) 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 methods and location of acquired imagery and enhancing future discoverability of the data.
2. Upload raw imagery from the survey to a secure, publicly accessible online repository (contact AODN if you require assistance in locating a suitable repository).
3. Create a Squidle+ campaign as soon as possible after imagery is uploaded, choose the most appropriate annotation schema, and commence annotation of imagery.
4. Add links to the location of the Squidle+ campaign to the previously published metadata record. You may also wish to attach or link a copy of the annotation data directly to the record.
5. Produce a technical or post-survey report documenting the purpose of the survey, sampling design, sampling locations, sampling equipment specifications, annotation schema (e.g. morphospecies, CATAMI, etc.), and any challenges or limitations encountered. Provide links to this report in all associated metadata *[Recommended]*

7.6.5 Data analysis

The breadth of research questions precludes any detailed advice on the analysis of data from underwater towed camera transects. However, one common attribute of the image-based data that will have to be contended with for all analyses is spatial proximity. The closeness of images, within and sometimes between transects, means that image data are unlikely to be independent (due to spatial autocorrelation). Yet, this is an assumption that most statistical methods rely upon. The failure to meet this assumption means that the inferences from the statistical analysis may be: (i) over-confident, e.g. having a p-value that is too small; (ii) biased, i.e. the estimates do not reflect the truth; (iii) both, or; (iv) no effect. Obviously, the fourth category is what a researcher hopes for, but it is improbable and must be validated. However, if it is known that the study organism exhibit particularly low autocorrelation at the scales of interest then the analysis need not consider it explicitly.

Methods to analyse data, accounting for autocorrelation are available. These include geostatistical models (see Foster et al. 2012 for an AUV-based example) and other models that incorporate dependence (e.g. Foster et al. 2009). However, in certain situations subsampling images will help (e.g. Mitchell et al. 2017 for a marine based example), but not necessarily alleviate it completely. Further, if the study is for a broad area, where transects are small and are well-separated, then amalgamating data to transect level may also be appropriate. The potential for observer bias, vignetting, and intra and inter station variability should also be carefully considered.

7.7 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 7 (field manual for towed camera) is below:

Version no	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
1.1	Link to Squidle+ corrected	March 2018
2	Relevant updates, including Data Release sections based on NESP, AODN, IMOS, GA, and CSIRO projects	Early 2019

Figure 7.2 Types of towed camera systems deployed in Australian waters. a) MNFs Deep Towed Camera platform; b) and c) AIMS towed camera platform being deployed off RV Solander; d) towed camera platform being trialled by Geoscience Australia off RV Southern Surveyor; e) and f) Deakin University towed video system.

Table 7.1: Types of towed camera systems deployed in Australian waters and their main characteristics. Note this list is not comprehensive. See reviews on towed cameras and perspectives in visual imagining for information about gear deployed elsewhere in the world (Durden et al. 2016a).

Towed Platform	Dimensions (W x H x L)	Weight (kg)	Max depth (m)	Camera system (video) & orientation	Camera system (stills) & orientation	Illumination	Laser(s)	Sensors	Suitable terrain	Example Reference
AIMS Towvid	~ 400 mm x 350 mm x 600 mm	~ 15 (Towed body only)	150	SD video forward facing Additional forward facing GoPro (HD) (optional)	12MP downward stills	Keldan 8M 8000 lumen floodlights (video) Inon D2000 strobe (still camera) synced to camera hotshoe by LED trigger and optic slave cable	In development		All, but steep inclines are best surveyed downslope; rugged terrain in low visibility is also risky.	(Nichol et al. 2013)
MNF Deep Tow		490	2500	Canon C300 high definition video camera paired with a Hitachi – HV-D30P Look Ahead Camera (8º) 1 x Watec 1/3" WAT231S with Avenir TTSG0234 lens	Digital Stills System Canon 1DX stills camera with a 18mm lens set at an oblique angle 8.3 Megapixel Lens Canon EFS10-22 F3.5-4.5 USM set to ~ 12 mm Strobes – dual Canon 580EX – ETTL mode Flash sync – Canon STE2 transmitter Stereo	2 x Deep Sea Power and Light – Deep Multi Sealites 250W each	2 x Laserex 10 mW (red) 16-laser array unit for stereo video calibration A pair of lasers with a known separation distance (10cm) is used as a reference for scaling objects and aligning video and stills in time.	Pressure: Druck PTX1400, range 0-250 Bar absolute Platform Pitch/Roll: Crossbow Dual Axis CXTA02 Tilt sensor Fluorometer: Seatech Serial No 100S Compass:Honeywell HMR3100 Altimeter: Datasonic/Benthos, PSA900 CTD: Falmouth Scientific 2" MicroCTD Serial #1468M Serial Interface: Quatech 4 port Serial Device Server	The Deep Towed Camera can only be deployed on a downhill/flat gradient and travelling towards deeper/open water to mitigate against winch failures	(Shortis et al. 2007, Sherlock et al. 2016)

					Cameras (50º) 2 x 1/3" 3CCD Hitachi HV-D30P with Fujinon TF2.8DA-8			Position: Sonardyne Super Sub Mini 7970 using channel H6 Sonardyne USBL Ver5.15C Transceiver # 1151 GPS: Vessel differential corrected Ashtech GGA,VTG		
NSW OEH	1100 L x 900 H x 500 W	15	200	Forward looking xx video camera at 30 degrees through Fibre Optic Cable; camera spec?	Downward looking stills Canon xx	Seagis LEDs + 2 Keldan	A pair of lasers with downward looking camera	Pressure, Camera Temperature, Applanix POS MV providing 100 Hz Roll/Pitch/Yaw and positioning (G2 GNSS), sounder depth, camera angle from horizontal, USBL 1500	All but relatively steep terrain – always planned downslope; usually <100m water depth, turbidity, wind waves and strong currents in nearshore limiting factor – small vessel ops	(Jordan et al. 2010)
Deakin	400mm*600mm x 300mm	20	120	SD video oblique facing Additional oblique facing STEREO HD GoPro with 400mm base bar	12MP downward stills with strobe	Video ray lights for oblique view and strobe for down facing imagery		HOBO Pendant temperature/light data loggers (UA-002-08) recorded mean light (lum/ft²) and temperature (˚C) at ten-second intervals for the duration of each deployment		(Logan et al. 2017)

Table 7.2: Sample field datasheet to record metadata (i.e. deployment or event data) from each towed camera deployment.

	Gear in water			Gear on bottom				Tow speed	Wire out (length)[1]	Wire out (angle) [1]	Gear off bottom				Gear out of water			Notes
Tow ID	Long	Lat	Time	Long	Lat	Depth	Time				Long	Lat	Depth	Time	Long	Lat	Time	

7.8 References

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