Pacific Islands Fisheries Science Center

Ecosystem Sciences Division
Standard Operating Procedures:
Data Collection for Towed-diver Benthic and Fish Surveys

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Contents

INTRODUCTION

This document is a guideline focused on towed-diver training, field sampling, and data entry for the monitoring of benthic habitat, select macroinvertebrates, and large-bodied (greater than 50 cm in total length) reef fishes and species of interest in shallow-water reefs as part of the Pacific Reef Assessment and Monitoring Program (Pacific RAMP) for the National Oceanic and Atmospheric Administration's (NOAA's) National Coral Reef Monitoring Program (NCRMP), led by the Ecosystem Sciences Division (ESD) of the NOAA Pacific Islands Fisheries Science Center (PIFSC). The standard towed-diver survey operating procedures outlined in this report apply to Pacific RAMP surveys that the ESD and its partners conduct across coral reef ecosystems in the Hawaiian Archipelago (including the Papahānaumokuākea Marine National Monument), the Mariana Archipelago (including Guam, the Commonwealth of the Northern Mariana Islands and the Marianas Trench Marine National Monument), the Territory of American Samoa (including Rose Atoll Marine National Monument), and the Pacific Remote Islands Marine National Monument (including Wake, Johnston, Palmyra, and Kingman Atolls and Howland, Baker, and Jarvis Islands).

BACKGROUND AND PURPOSE

Towed-diver surveys use an open-circuit scuba technique similar to manta tow snorkel surveys conducted by the Australian Institute of Marine Sciences (AIMS) Long-Term Monitoring Program (LTMP) and the Global Coral Reef Monitoring Network (GCRMN). Manta surveys were originally developed in the 1960s and 1970s to count crown-of-thorns sea star (COTS) (*Acanthaster planci*) across coral reefs of the Pacific Ocean (Goreau et al. 1972, Endean & Stablum 1973). In the 1980s, they were further standardized to conduct broad-scale benthic assessments on the Great Barrier Reef by AIMS (Moran et al. 1988). Validation studies (Fernandes 1990, Moran & Death 1992) confirmed that manta tow surveys were relatively accurate, cost effective, and reasonable predictors of the abundance of COTS and coral cover over large areas. Additional estimates of living soft coral and recently dead hard coral also allowed for the assessment of the impact of COTS outbreaks and other large-scale disturbances. The first towed-diver surveys at the NOAA Honolulu Laboratory (now PIFSC) were a variant used by Dr. Frank Parrish in the 1990s as a means to survey lobster habitat in the Northwestern Hawaiian Islands (NWHI), targeting deeper depths (35–40 m) primarily along oceanic banks (Parrish & Polovina 1994; Fig. 1). The approach was later modified and adapted by the NOAA PIFSC ESD for shallow-water coral reef benthic habitat (Kenyon et al. 2006), macroinvertebrate, and reef fish assessments (Holzwarth et al. 2006; Richards et al. 2011).
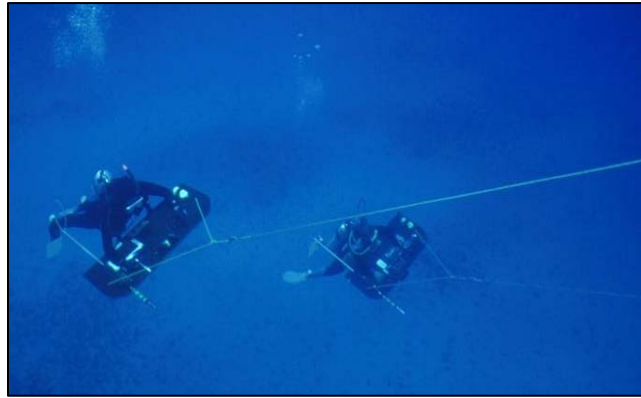
Figure 1. Deep bank towed-diver surveys in the Northwestern Hawaiian Islands. NOAA photograph

In-situ survey techniques, such as 'rapid ecological assessments' (REA), provide detailed information on benthic, invertebrate, and fish communities at small scales, e.g. ~ 350 m^2 of reef per survey (Ayotte et al. 2015). By contrast, towed-diver surveys generate broad-scale information over much larger areas (mean length of a tow is 2.2 km, with a transect area of 22,000 m^2). Towed-diver surveys consist of two divers, one dedicated to the assessment of fish assemblages and the other dedicated to recording benthic habitat and conspicuous macroinvertebrates; which will be referred to as the fish diver and the benthic diver, respectively. These divers are pulled 60 m behind a small boat, targeting a 15-m depth contour as they survey the area 5 m on each side of the tow line while staying approximately 1 m above the benthos during the survey (Fig. 2).

Figure 2. Towed diver top and side view.

Unlike in-situ surveys that require divers to be close to the reef substrate in relatively calm waters, towed divers are able to operate in exposed areas subject to higher wave energy conditions (e.g. on windward facing shores). These broad-scale surveys provide information on large-bodied roving fish assemblages, such as sharks and jacks that are generally not well sampled by REA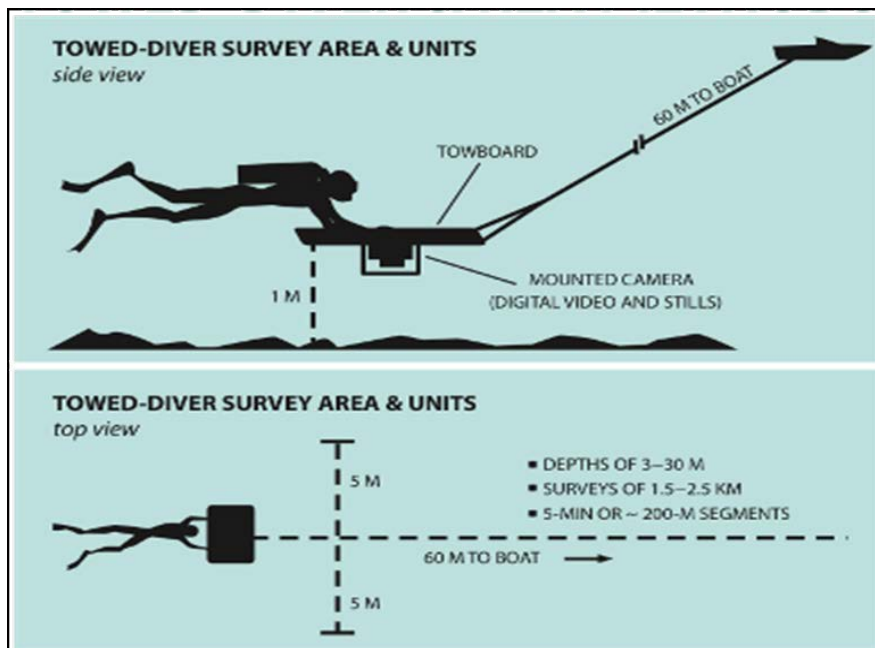 surveys. The towed-diver approach provides information on rare or patchily distributed organisms that are inherently hard to survey in small areas, such as crown-of-thorns seastars (COTS), giant clams, sea cucumbers, and urchins, and can detect unusual or important sightings (natural or anthropogenic sources), such as derelict fishing gear, shipwrecks, and unexploded ordnance. Towed-diver surveys gather archival downward-facing photographic still imagery, forward-facing video imagery, and temperature and depth recorded every 5 sec on data loggers.

TOWED-DIVER FIELD METHODOLOGY

Requirements and Training

Towed-diver candidates must meet several pre-training qualifications which include: 1) one year of experience as a certified NOAA scientific or working diver; 2) a minimum of 10 logged dives greater than 100 ft; 3) successful completion of the PIFSC Advanced Coxswain certification or the Motorboat Operator Certification Course (MOCC) with the accompanying Open Water Module (OWM); and 4) one year of coxswain experience. Once these qualifications are met, candidates are trained by the PIFSC Unit Dive Supervisor (UDS) in operating the towboard and in emergency rescue and recovery scenarios.

After completing towboard operation training with the UDS, divers must also complete a comprehensive advanced towed-diver survey training to learn and become familiar with standard towed-diver operations (see Appendix J). Benthic divers are specifically trained in identifying corals, macroalgae, CCA, and invertebrates, and learn to estimate percentage cover of the benthos, as well as quantities of specific invertebrates. Fish divers are trained in identifying and estimating sizes of targeted fishes using region-specific training guides and participate in regular training dives to practice estimating sizes of underwater models of various fish species and sizes to improve inter-observer accuracy. Both benthic and fish divers collaborate with experienced towed-diver survey scientists, and conduct frequent calibration dives.
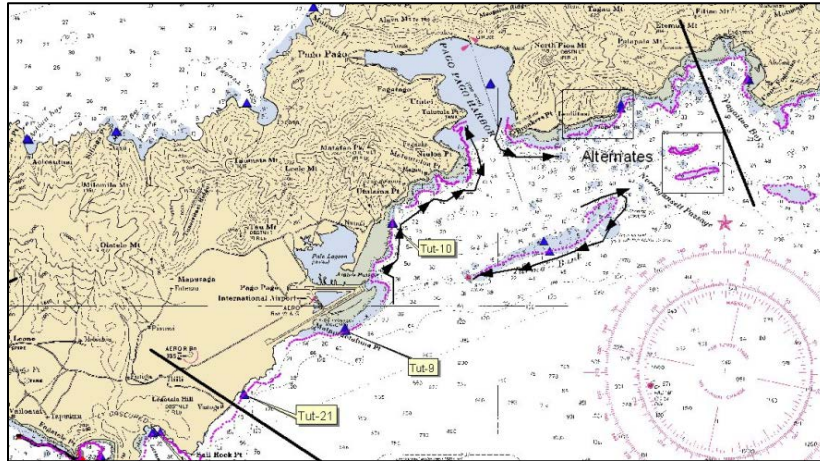
Figure 3. Historical tow track lines at Tutuila, American Samoa. NOAA chart.

Towed-diver survey track line planning—where the divers will be towed—is typically based on historical towed-diver survey track lines developed and recorded by following depth contours with guidance from survey charts (Fig. 3). The historical towed-diver survey tracks are loaded into the small boat's GPS/chartplotter (Fig. 5) and are then used by the coxswain as a general guideline for where to navigate the boat. (Appendix C). Factors that guide the current approach towards towed-diver surveys include the following (in order of relative importance):

- Assessing benthic habitat condition on a large scale
- Mapping and related projects (e.g. generating or validating GIS map layers of habitat type)
- Assessing the status of highly mobile large-bodied fishes (e.g. roving predators, vulnerable and protected species)
- Assessing the status of conspicuous economically or ecological-important macroinvertebrates (COTS, giant clams, sea cucumbers, urchins).

Figure 4. Towboards and instrumentation. The fish towboard is on the left, the benthic towboard is on the right.

Equipment and Operations

Shallow-water habitats (<30 m) around each island, bank, or reef are surveyed using diver controlled towboards (Fig. 3), which are each equipped with:
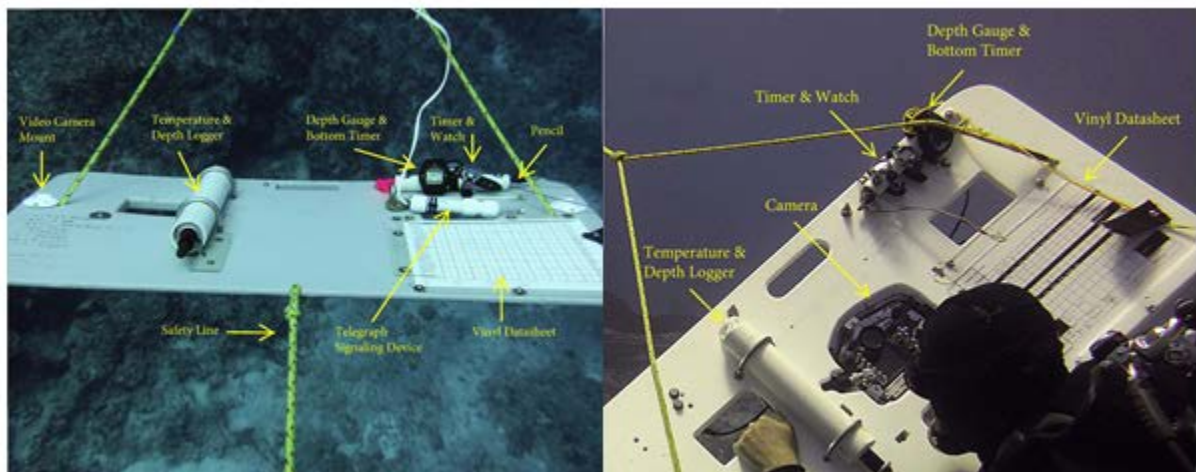
- Pre-printed vinyl data sheet
- Pencil
- Watch for 5-min cycling
- Watch with current local time
- Depth gauge and bottom timer
- Temperature/depth logger
- Still camera, (benthic towboard)
- Video camera, (fish towboard)
- Telegraph (fish towboard)

Surveys are conducted by a team of four individuals, which consist of an alternating diver pair and a surface pair (who serve as coxswain and one surface support team member to assist with the deployment and recovery of the dive team). At the end of each survey, the dive and surface pairs switch roles, allowing the dive pair a minimum of a 1-hr surface interval between dives. Divers are towed underwater using 60-m lines at 1–2 kn behind a 19' (5.8-m) SAFE™ vessel (hereafter referred to as "small boat"), approximately targeting the 15-m depth contour.

Towboard Equipment and Configuration

Towboards are constructed of StarBoard™ marine polymer sheets 1 m × 0.5 m × 2 cm. One towboard is designed for benthic habitat observations while the other is designed for observing fish populations. The benthic towboard is outfitted with a downward facing Nikon™ D7100 DSLR camera in a waterproof Ikelite™ housing attached to the underside of the towboard in a protective stainless steel bracket, with two Ikelite™ DS 51 strobes connected to the camera housing. The camera is set to photograph the benthos at 15-sec intervals for the duration of each 50-min survey.

The fish towboard is outfitted with a forward facing GoPro® Hero 3+ Silver Edition high definition digital video camera in a waterproof housing. Both towboards are outfitted with SeaBird™ SBE39 temperature/depth loggers set to record at 5-sec intervals (Appendix E), which are inserted into a protective PVC tube and secured with a bolt and wingnut; two stop watches for timing the survey (one with a 5-min segment cycling countdown alarm, one with local time which is used to denote the start/end survey times); an Uwatec™ bottom timer and depth gauge; and a vinyl data sheet (either benthic or fish). All timing devices are set to local time and are synchronized weekly using the network clock on the research vessel. An underwater telegraph is also attached to the fish towboard, which is used to communicate key navigation (e.g. start, stop, left, right) or safety (e.g. stop/help) messages with the team on the surface via a modified "Morse code" (see Appendix H). Since the benthic diver does not have a telegraph system, the fish diver is responsible for all communications with the vessel, including directional signaling.

GPS Tracking

A GPS unit is used on the small boat (Fig. 5) to record survey track points at 5-sec intervals. An additional GPS unit is used as a backup in case the primary GPS encounters any issue. It is critical for the coxswain to start tracking on the GPSs at least a minute prior to the start of the first survey to record the vessel's path, and both GPS units can be left tracking until after the last towed-diver survey. A custom algorithm developed by ESD is later used to calculate the track of the divers based on the track, speed, and course of the small boat, along with diver depth.

Figure 5. Onboard GPS/chartplotter and separate GPS unit.

Starting a Survey

Once in the water and at the surface, the fish diver tests the underwater telegraph and waits for an "OK" hand signal from the coxswain or surface support team member before descending. The fish diver is always positioned on the side of the vessel opposite of the reef crest, while the benthic diver is always closer to the reef crest. If the fish and benthic divers need to switch sides prior to beginning the survey, the lines and boards can either be swapped on the vessel (easier before boards are attached), or in the water (easier when boards are already attached to the lines). When lines are swapped in the water, the vessel pays out the entire length (60 m) of both lines, shifts into neutral temporarily, disconnects the lines from the vessel and swaps lines with the benthic (floating) line over the top of the fish (sinking) line. During this time, the benthic diver swims over the fish diver to the position closest to the reef crest.

Divers descend to a depth of roughly 15–18 m while the surface support team member on the vessel slowly pays out the tow lines. At this time, both divers power on their respective tow equipment and begin recording. When the divers reach the target depth and are ready to start the survey, they exchange a 'start survey' hand signal. When the signal is given, each diver records the start time on the data sheet in hours, minutes, and seconds (hh:mm:ss), and starts their respective 5-min countdown timers on a watch attached to each towboard. Following the 'start survey' signal exchange, the benthic diver powers on the DSLR camera. The camera is

programmed with a cycling timer, which automatically takes a photograph of the benthos every 15 sec for the duration of the survey. Strobe lights may also be powered on, dependent on background lighting encountered at survey depths. The fish diver signals 'start survey' to the vessel via the underwater telegraph, with the coxswain concurrently marking a waypoint on the handheld GPS and starting a countdown timer on the boat console to monitor 5-min segments and total survey time.

Conducting a Survey

Each survey is divided into ten 5-min survey segments (50-min total survey time). On the towboard, the countdown timer sounds an audible alarm every 5 min, prompting the divers to end one segment and start another. After each 5-min segment, the fish diver will telegraph an "ok" to the coxswain. Each diver observes a 5-m swath on both sides of the tow lines (10-m total). The divers also note average visibility for the entire survey, which can be measured by using the towboard line as a visual reference. The line is marked in 5-m segments with contrasting-colored electrical tape for this purpose.

Ending a Survey

At the end of the survey, the fish diver records the stop time (hh:mm:ss), stops recording video, and signals to the vessel that the survey has ended. The benthic diver concurrently switches off the DLSR and strobes (if used), and similarly marks the survey end-time. The coxswain marks a second waypoint on the GPS and veers slightly offshore (as necessary) as both divers slowly ascend to their safety stop. At the end of the safety stop, the fish diver signals the vessel to stop, the coxswain shifts the engines into neutral, and the coxswain and surface support team member pull in the tow lines while the divers swim the towboards back to the vessel.

Diver Safety

After each 5-min segment of the dive, the divers exchange the "OK" signal. Each diver is monitoring the other throughout the duration of the dive, and remains close enough to render assistance if needed. In an emergency, the fish diver sends a "stop" signal to the small boat. If the fish diver is compromised due to dive emergency or injury and is unable to operate the telegraph signal, then the benthic diver maneuvers to the fish towboard to operate the telegraph signal. The divers can then ascend to the surface or continue the survey if the issue can be quickly resolved and does not pose a continuing safety hazard.

Towboards are designed to dive downward if unmanned, and thus act as an anchor to inform the vessel operators of a potential emergency situation. This feature also alerts the benthic diver to an emergency, so that the benthic diver can get to the fish board in the event that the fish diver falls off. If the surface support does not receive a signal at a given 5-min interval, they will rev the engine once. If no signal is received after an engine rev, they will repeatedly rev the engine, signaling to end the survey and for divers to return to the surface. Each towboard is equipped with a polypropylene rope tag line, which is attached to the rear of the board. If a diver loses grip on the board, that person is able to grab the tag line trailing behind the towboard and easily pull themselves back to the towboard.

A towed-diver survey may be ended early due to safety concerns (e.g. poor visibility, strong currents, diver fatigue, etc.), or if the small boat is recalled by the main NOAA research vessel. Either the coxswain (using engine revs or diver recall device) or the divers (telegraphed end-survey signal) can end a survey early if they deem it appropriate. In these cases, data sheets are marked with the code 'No Score' (NOSC) for fish and 'No Data Recorded' (NDR) for benthic for any segments in which data was not taken or conditions are too poor to collect quality data.

Fish and megafauna (including sharks) display minimal attraction or aversion to the towed divers moving in the water column. The indifference observed allows for quality in situ observations with no recorded injuries or incidents of aggression directed towards divers.

Fish Data Collection

The fish towed-diver records all species and total length (TL, Figs. 6 & 7) for each individual fish observed that is greater than or equal to 50-cm TL. The survey area extends 5 m to each side and 10 m in front of the diver, from the reef to the ocean surface. Fish are identified to the lowest possible taxon and are sized to the nearest cm. Fish species are recorded using 4-letter codes typically based on the first 2 letters of the fish genus and the first 2 letters of the species (e.g, *Caranx ignobilis* is recorded as CAIG). Divers attempt to accurately represent the abundance of fish of different sizes, as to better reflect the size distributions of individual species. Divers avoid giving an average size for a large school of fish whenever possible. Data are recorded on standardized vinyl data sheets, which have pre-entered sections for common species (Fig. 8).
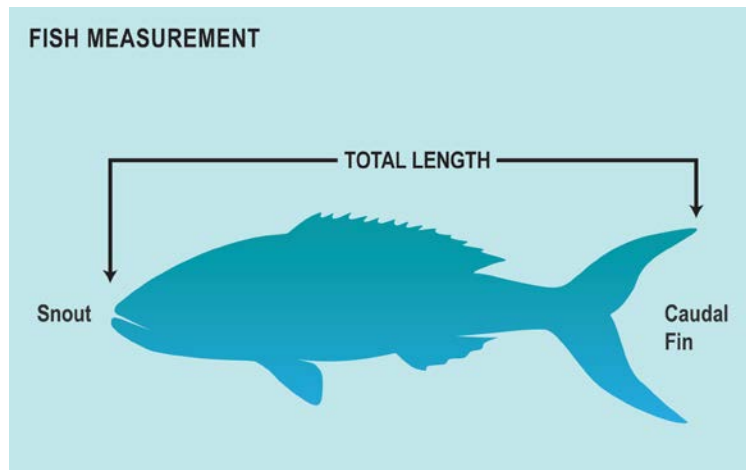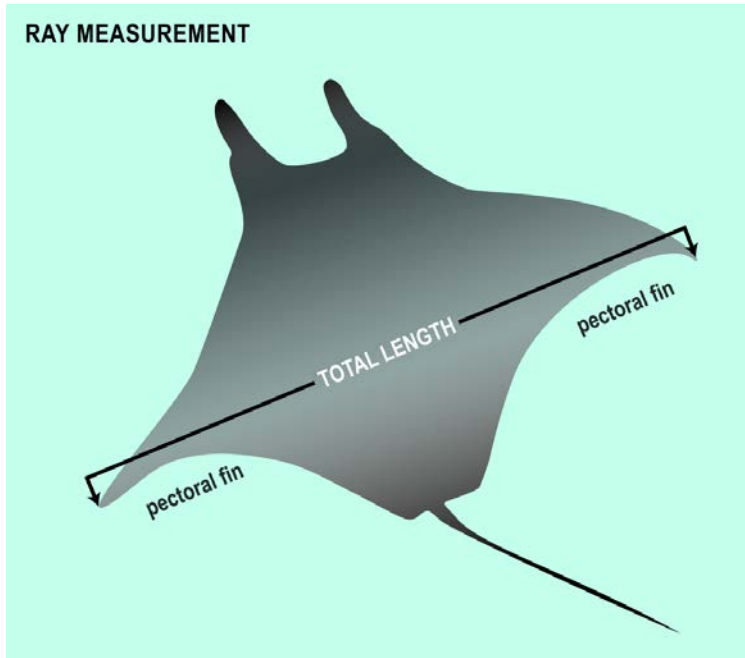

Figure 6. : Illustration of total length measurement.

Figure 7. Illustration of total length measurement for rays.

Figure 8. Sample of a fish towed-diver data sheet.

Sighting Data

Sea turtles, cetaceans, pinnipeds, and three fish 'species of interest' are recorded, regardless of size, or location inside or outside the survey area. Fish species of interest include: humphead wrasse (*Cheilinus undulatus*), giant grouper (*Epinephelus lanceolatus*), and bumphead parrotfish (*Bolbometopon muricatum*). If these fishes are less than 50-cm TL or are recorded outside the survey area, they are circled on the data sheet and entered into the sightings section of the database, along with any sea turtle, cetacean, or pinniped sightings. Data on other rare species of importance, range extensions or unique records, or significant occurrences (e.g. large spawning aggregations) are also recorded in the sighting database.

The fish towed divers are trained in identifying and sizing anticipated large fishes using region-specific training guides and participate in regular training dives to practice estimating sizes of underwater models of various fish species and sizes to improve inter-observer accuracy. [1]

Benthic Data Collection

The benthic towed divers gather in-situ data on the habitat and key conspicuous ecologically or economically important invertebrate categories. They record: 1) percentage cover of total live hard corals, stressed hard corals, soft corals, sand, coralline algae, and macroalgae; 2) an estimation of the number of individual crown-of-thorns seastars (COTS), sea urchins, giant clams, and sea cucumbers; and 3) an estimation of the complexity and zone type of the observed habitat (Figure 9).

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[1] https://www.pifsc.noaa.gov/cred/survey_methods/fish_surveys/rapid_ecological_assessment_of_fish-survey_method_training.php

TOWBOARD HABITAT SURVEY								Fish Tow Tape #		
Time Segment	1	2	3	4	5	6	7	8	9	10
Complexity										
Habitat										
CORAL	0.1-1%	1.1-5%	5.1-10%	10.1-20%	20.1-30%	30.1-40%	40.1-50%	50.1-62.5%	62.6-75%	75.1-100%
Total Hard										
Stressed Hard										
Soft										
SAND										
RUBBLE										
ALGAE										
Macroalgae										
Coralline										
INVERTS	26-50	51-100	101-250	251-500	501-1000	> 1000				
COT										
Sea Urchins (Free/Bor)	/	/	/	/	/	/	/	/	/	/
Sea Cucumbers										
Giant Clams										
COMMENTS										
Date:	Dive #:		Towline (m):		Time Start: : :			Zone:		
					Time Stop: : :					
Reef:	Diver:		Avg. Vis. (m):							

Figure 9. Benthic towed-diver data sheet.

Habitat complexity

Towed-diver surveys collect habitat complexity data based on a six-point subjective assessment of topographical diversity and complexity of the benthic habitat: low (L), medium-low (ML), medium (M), medium-high (MH), high (H), and very high (VH) (Fig. 11). Divers record the average complexity of the habitat observed during each 5-minute segment (Fig. 10). Low habitat complexity is often associated with flat sand plains or rubble habitats. Medium habitat complexity is often associated with small to moderate spur and groove, coral or boulder habitats. High, or very high habitat complexity is often observed as extreme vertical relief associated with steep spur-and-groove canyons, pinnacles, and walls (or a combination thereof).

TOWBOARD HABITAT SURVEY								Fish Tow Tape #		
Time Segment	1	2	3	4	5	6	7	8	9	10
Complexity										
Habitat										
CORAL	0.1-1%	1.1-5%	5.1-10%	10.1-20%	20.1-30%	30.1-40%	40.1-50%	50.1-62.5%	62.6-75%	75.1-100%

Figure 10. Habitat and complexity sections of the benthic towed diver data sheet.
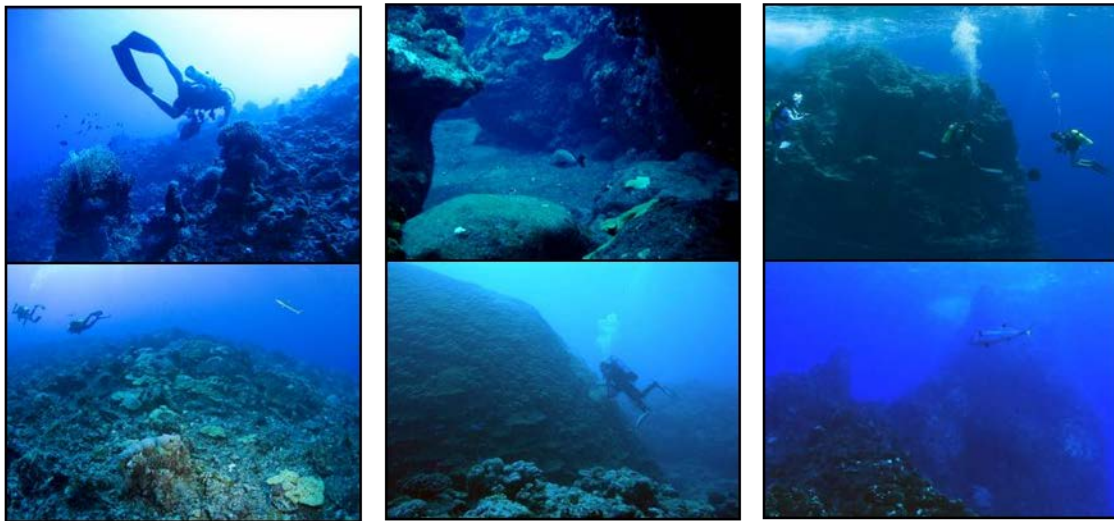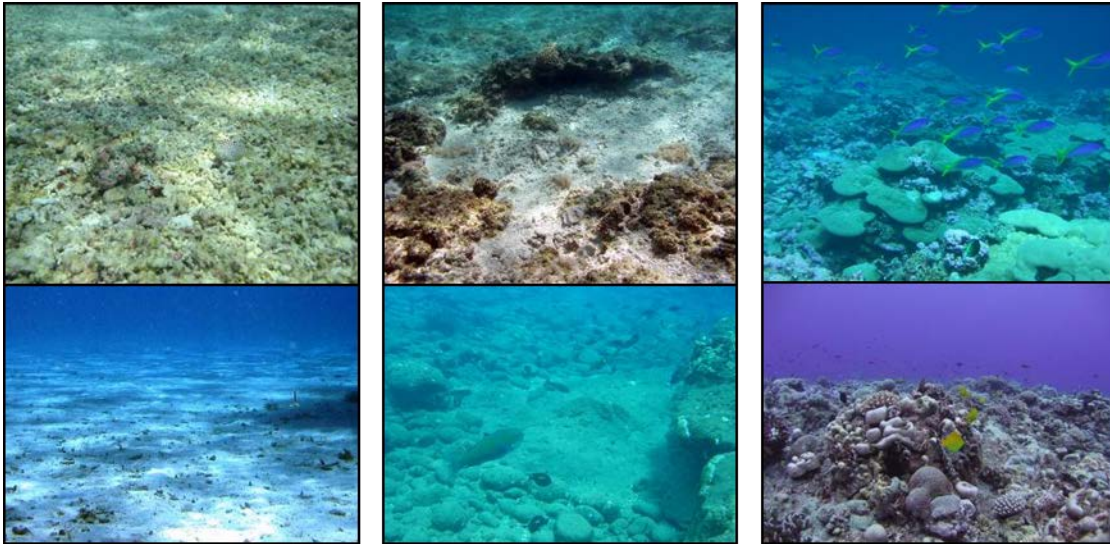
Figure 11. Habitat complexity types categorized by benthic towed divers.

Habitat type

Benthic towed divers identify the habitat type and record it as a two-letter code. If divers tow through more than one habitat type or a reef area during a 5-min period they record and enter two codes (e.g. CR/SG, PV/RB). The habitat categories are: Continuous (aggregate) reef (CR), Spur and Groove (SG), Patch reefs (PR), Rock Boulders (RB), Pavement (PV), Rubble Flat (RF), Sand flats (SF), Pinnacle (PI), and Wall (WA) (Figs. 12a–i).

Continuous (aggregate) reef (CR): Continuous aggregate reef consists of consolidated, carbonate reef structures lacking sand channels, or spur and groove habitats (Fig. 12a). This is the most common category recorded along forereef habitats and includes linear reef formations oriented parallel to shore or shelf edges. CR differs from the pavement category in that CR is a more

rugose habitat containing topographic features such as holes and reliefs. CR is generally higher on the scale of habitat complexity.

Figure 12 a. Example of continuous aggregate reef. NOAA photo.

Spur and Groove (SG): Spur and groove is a wave-induced habitat containing alternating grooves or "valleys" of sand and spurs or "ridges" of coral formations that are perpendicularly oriented to the shore or bank/shelf escarpment (Fig. 12b). The spurs typically have high vertical relief of corals, separated by sand channels or carbonate rubble in widths typically 1–5 m. The height and width of both elements may vary considerably depending on wave energetics. This habitat type is commonly paired with continuous (aggregate) reef (CR).

Figure 12 b. Example of spur-and-groove habitat. NOAA photo.

Patch reefs (PR): Patch reefs are comprised of a comparatively small assemblage of coral colonies or consolidated carbonate formations that are isolated from other coral reef formations by sand, seagrass, or other habitats and that have no organized structural axis relative to the contours of the shore or shelf edge (Fig. 12c). It is most commonly noted in lagoons (e.g. Rose Atoll) or backreefs (e.g. northern Pearl and Hermes/Midway).

Figure 12 c. Example of patch reefs habitat. NOAA photo.

Rock/Boulders (RB): Rock boulders comprise solid carbonate blocks and/or boulders or volcanic rock (Fig. 12d).

Figure 12 d. Example of rock/boulder habitat. NOAA photo.

Pavement (PV): Pavement is a flat, low-relief, consolidated substrate typically composed of calcareous and/or basaltic elements, which have become cemented together by biogenic and

physical processes (Fig. 12e). Coverage may include macroalgae, hard coral, zoanthids, and other sessile invertebrates that may be dense enough to begin to obscure the underlying surface. It differs from CR in that PV is low relief and has none or minimal rugosity/structure to the reef. Its complexity will always be low (or medium-low in some cases).

Figure 12 e. Example of pavement habitat. Photo by D. White, Hawai`i Department of Land and Natural Resources.

Rubble Flat (RF): Rubble flats are composed of dead, unstable coral pieces often colonized with macroalgae, crustose coralline algae, turf algae, or small scleractinian coral colonies. (Fig. 12f). This habitat most often occurs landward of well-developed reef formations along reef crests or backreef zones. It can occur in low density aggregations adjacent to broad offshore sandy areas and can be found in areas subjected to high wave action, areas impacted by weather events (typhoons, tsunamis) or areas subjected to mass-wasting/landslides.
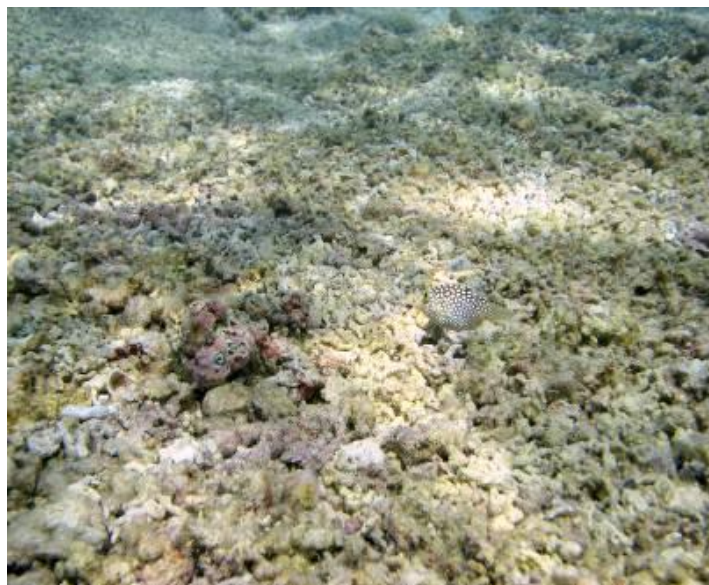

Figure 12 f. Example of rubble flat habitat. NOAA photo.

Sand flats (SF): Sand flats are expanses of nearly featureless coralline or coralline-algae generated particulates and are commonly found in large stretches of lagoon habitat, along shorelines where beaches are present, and at the bottom forereef slopes (Fig. 12g). Complexity will be low.
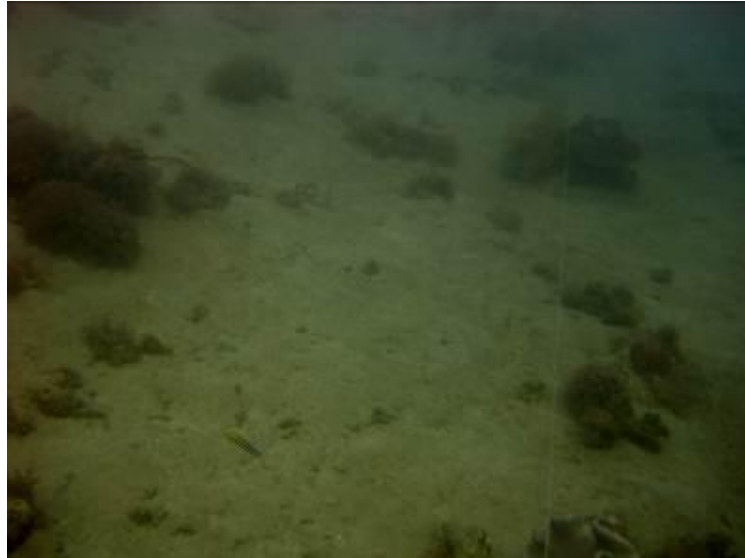

Figure 12 g. Example of sand flat habitat. NOAA photo.

Pinnacle (PI): Pinnacles include isolated spires or a series of spires composed of rock and/or coral that may extend above the surface of the water (Fig. 12h). Complexity of an area with many pinnacles may be very high.

Figure 12 h. Example of a pinnacle habitat. NOAA photo.

Wall (WA): Walls are vertical, or near vertical, reef composed of carbonate or basalt and may or may not be colonized with benthic biota (Fig. 12i).
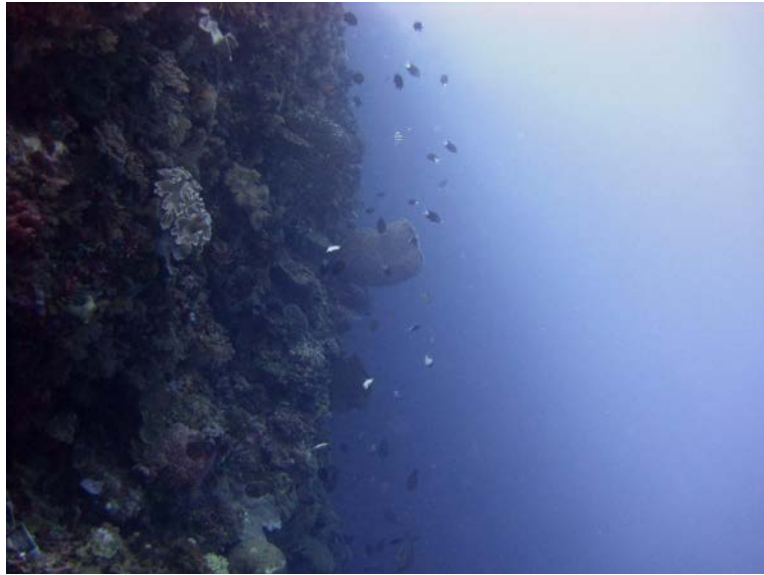
Figure 12 i. Example of a wall habitat. NOAA photo.

Benthic classification categories

Percentages of benthic cover are estimated for six categories: hard coral, stressed hard coral, soft coral, macroalgae, crustose coralline algae, and sand. For each category, the diver records a percent cover bin number between 0 and 10 that represents a percent range. (Table 1) Figure 13 is a visual representation of the various bin categories

Note: the total percentage cover will not always add up to 100%, as several habitat categories (e.g. turf algae, cyanobacteria) are not included. Note also that percentage cover should be estimated from a planar view of the substrate (from above) and not from a side (vertical) view.

Table 1. Benthic cover categories and corresponding percentile ranges for towed-diver surveys.

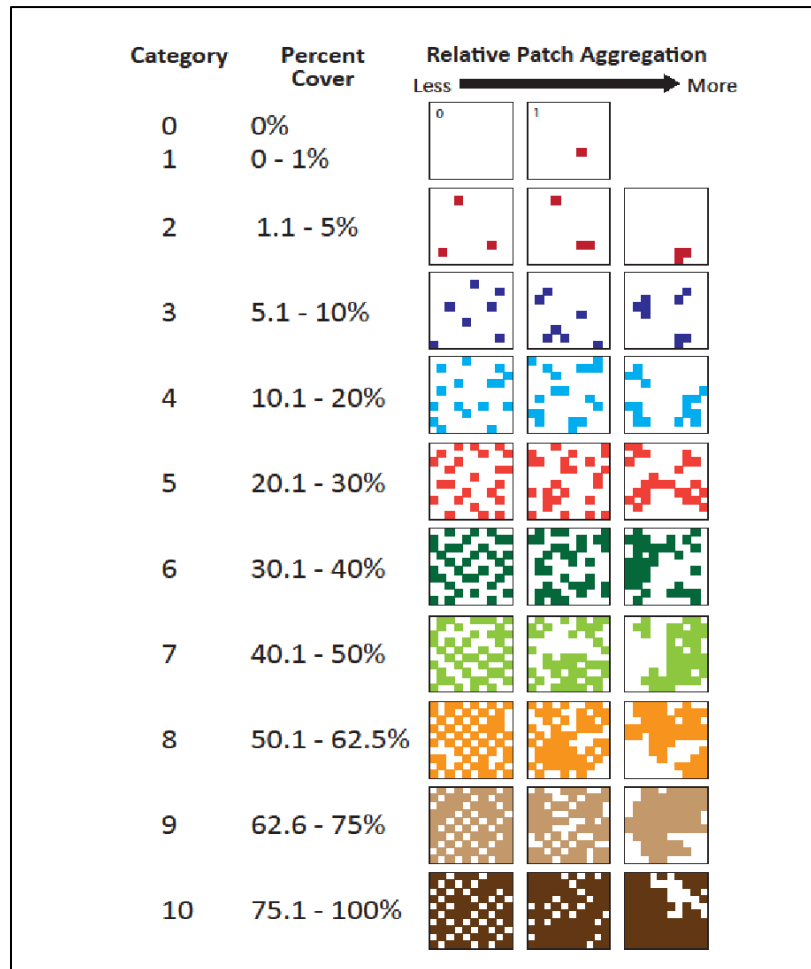| CREP	
Percent cover Bins	Percent Range
0	0
1	0 - 1
2	1.1 - 5
3	5.1 - 10
4	10.1 - 20
5	20.1 - 30
6	30.1 - 40
7	40.1 - 50
8	50.1 - 62.5
9	62.6 - 75
10	75.1 - 100

Figure 13. Benthic classification categories.

HARD CORAL

Hard corals are defined herein as those in the Phylum Cnidaria responsible for the hard, three-dimensional structure of a coral reef. This classification includes all members of Order *Scleractinia* and some other small groups of non-scleractinian corals with hard skeletons, including fire corals (Family *Milleporidae*), blue coral (Order *Helioporacea*), and Stylasterid hydrocorals (Family *Stylasteridae*) (Fig. 14).

Figure 14. Hard corals.

Observers record live hard coral species observed in the 10-m wide tow swath, characterized by colonies or portions of colonies that are covered with living tissue. Living tissue usually appears colored due to presence of pigments in coral tissue and/or their symbiotic zooxanthellae.

STRESSED CORAL

Stressed coral is defined as live hard coral that appears to be stressed as a result of loss of zooxanthellae and/or their pigments (Fig. 15). Stressed corals can have pale coloration or white color due to bleaching or COTS predation, disease or recent death. Recently dead coral is coral that has been dead approximately 1 year or less and can have growth of turf and/or macroalgae on the formerly living coral skeleton. Dead coral with growth of macroalgae or visibly encrusted by epiphytes would be considered part of the macroalgae category or uncounted substrates, respectively. Recently dead coral that has been degraded into rubble or has otherwise lost its living form is also not counted in this category. It may be hard to differentiate between recently dead and severely bleached corals. For this reason, they are both classified as stressed.

Benthic towed divers estimate the percentage of live coral that appears stressed. For example, a diver records within a 5-min segment, a 7 for coral cover (40.1–50%)) and a 4 for stress (10.1–20%). Taking the mean values, this is interpreted as 15% of the 45% recorded coral cover was stressed.

'Stressed hard coral' data is recorded only if it is greater than 10%. Divers note in the "Comments" section the type of coral stressor being observed.
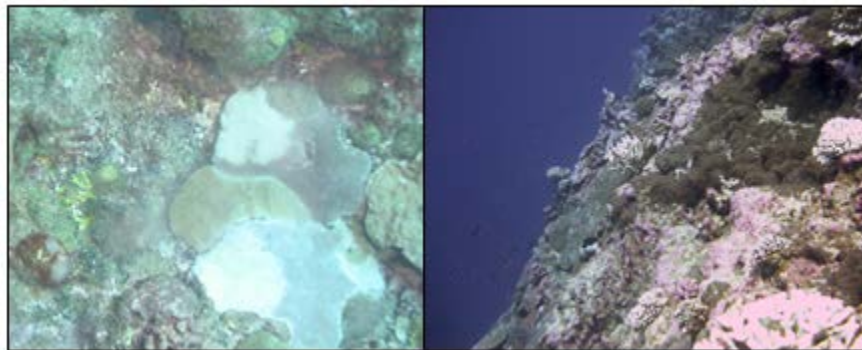

Figure 15. Stressed corals.

SOFT CORAL

Soft corals are defined as those in the Phylum Cnidaria that are not responsible for the hard, three-dimensional structure of a coral reef. This includes true soft corals, sea fans, sea whips, sea pens, and other members of the octocorals (Subclass *Alcyonaria*) (Fig. 16), except blue coral (Order *Helioporacea*), which is recorded under Hard Coral.
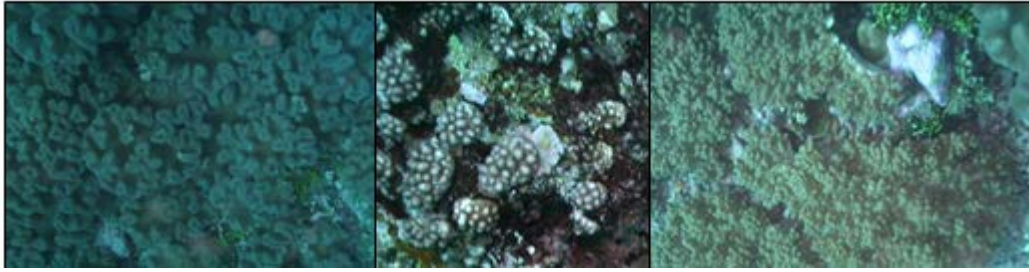
Figure 16. Soft coral.

Macroalgae are usually larger canopy-formers, including brown algae (*Dictyota*, *Sargassum*), red algae (*Gracilaria*, *Laurencia*), green algae (*Caulerpa*, *Microdictyon*) and can be either fleshy (e.g. *Asparagopsis*) or calcareous (e.g. *Halimeda*), and do not include algal turfs (Fig. 17). Any alga whose structure can be seen by benthic towed-divers should be labeled as macroalgae cover. Macroalgae possess numerous different types of morphologies that can include: leaves, blades, umbrellas, ferns, grapes, balls, feathers, and branched shrubs.

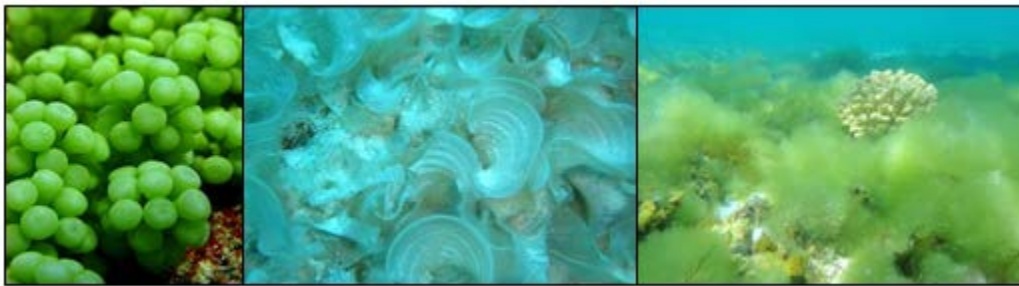Encrusting macroalgae (e.g. *Lobophora sp*. and *Peysonnellia sp*) are not included.

Figure 17. Macroalgae.

CRUSTOSE CORALLINE ALGAE (CCA)

Crustose coralline algae herein are defined as any calcified, hard, non-segmented, encrusting or branched, red (pink or purple) alga (Fig. 18).

CCA commonly grows in patches on hard substrates, ranging from pavement flats to basalt formations to bare carbonate (i.e. coral skeleton) structures. CCA also commonly grows on rubble, which is defined as hard fragments (e.g. rocks, pebbles, pieces of dead coral) typically of gravel (> 5 mm) and cobble (baseball) size with finer and coarser sediments mixed in, in patches.
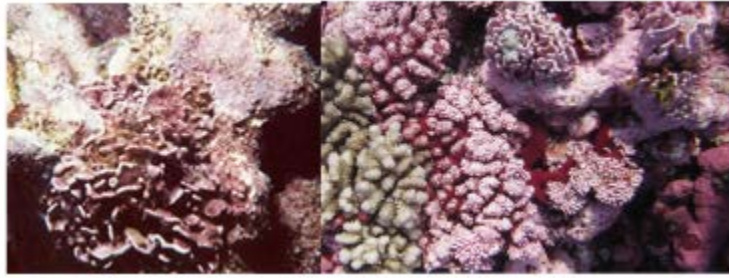
Figure 18. Crustose coralline algae.

SAND

Sand is defined as unconsolidated sediment with a grain size between 1/16 mm and 5 mm, ranging in texture and size from fine to coarse. Origins are both inorganic (eroded rock) and organic (eroded fragments of calcareous organisms, e.g. *Halimeda* or scleractinian corals).

Benthic towed divers count sand as substrate that consists of thick sandy substrate habitats (e.g. sand channels in spur and groove habitats, deep sand pockets) and not the thin layers that at times are coating pavement and continuous reef habitats (Fig. 19).
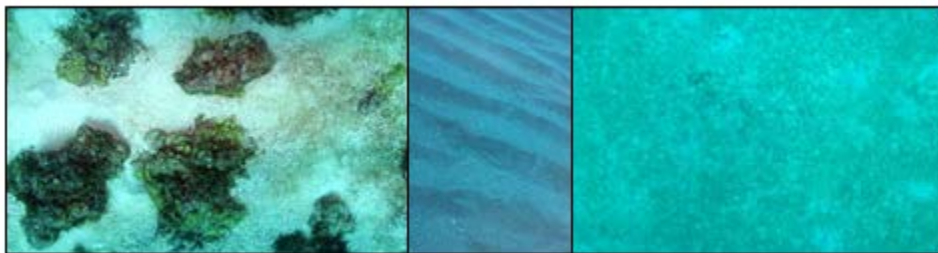

Figure 19. Sand.

MACROINVERTEBRATES

The following macroinvertebrates are recorded by benthic towed divers:

Crown-of-thorns seastar/COTS (*Acanthaster planci*)

"Boring" sea urchins (e.g. *Echinostrephus*, *Echinometra*)

"Free" sea urchins (e.g. Tripneustes, Diadema, Echinothrix)
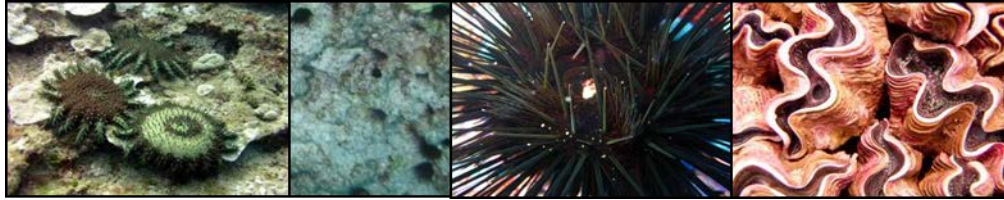
Giant clams (*Tridacna* sp.)

Figure 20. Macroinvertebrates.

Macroinvertebrates are counted independently up to 25 individuals. Above that, quantities of each macroinvertebrate taxa are recorded in the following bins (Fig. 21):

Category 1: 26 – 50 (1 with a circle around it; same for subsequent categories)

Category 2: 51 – 100

Category 3: 101 – 250

Category 4: 251 – 500

Category 5: 501 – 1000

Category 6: > 1000

Figure 21. Macroinvertebrate section of the benthic towed-diver data sheet.

MARINE DEBRIS

Anthropogenic marine debris is noted in the "Comments" section and is tallied in a manner similar to macroinvertebrates (see above). Debris items include: (1) derelict fishing gear—nets/lines, (2) munitions, or unexploded ordinances, (3) shipwrecks, and (4) other man-made objects, whether of nautical or terrestrial origins, e.g. anchors/discarded mooring, tires, and corrugated tin roofing (Fig. 22). It is important to note that marine debris observations do not include smaller, highly mobile marine debris such as bottles, cans, plastic bags, etc. Benthic towed divers should only collect marine debris data opportunistically, i.e., if it does not interfere with the collection of the benthic data listed above (coral, macroalgae, invertebrates, etc.).
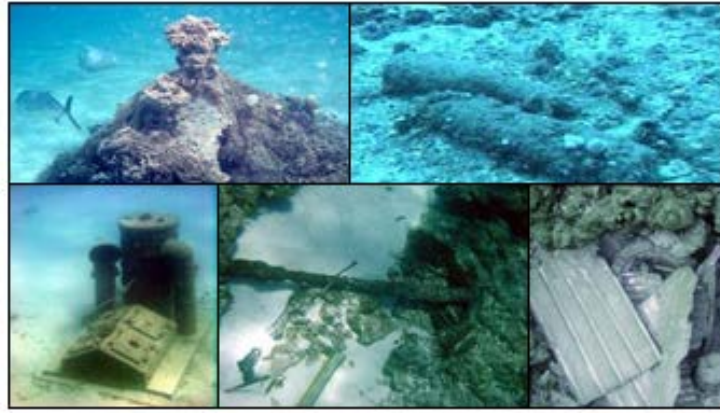
Figure 22. Marine debris.

If the area appears to be a dump, wreck, or high-density munitions site, divers should note the local starting/ending times where the site is located. Divers can also send a telegraphed "mark signal" to the small boat as backup, where the coxswain/surface support will take a waypoint on the GPS and make a notation in the Navigation/Dive metadata.

UNIQUE OR UNUSUAL OBSERVATIONS/EVENTS

Unique or unusual events previously documented during towed-diver surveys include coral bleaching in the NWHI, the aggressive growth of the macroalgae *Boodlea composita* at Midway Atoll and Kure Atoll in the NWHI (Vroom et al., 2009; Fig. 23), and the aggressive growth of the diademnid tunicate *Diplosoma similis* at Swains Island in American Samoa (Vargas-Angel et al., 2009). Unique or unusual events are noted within the "Comments" section of the data sheet. If the event is extensive (e.g. widespread coral bleaching), the cover is quantified using the benthic category bins (1: 0–1%, 2: 1.1–5%, etc.) previously described and the start/end times of sighting are recorded. If possible, voucher photographs should be taken to document these events.

Figure 23. I) Coral bleaching at Howland, PRIA; II) Boodlea growth at Midway Atoll, NWHI; III) Tunicate *Diplosoma similis* growth at Swains Island, American Samoa. NOAA photographs.
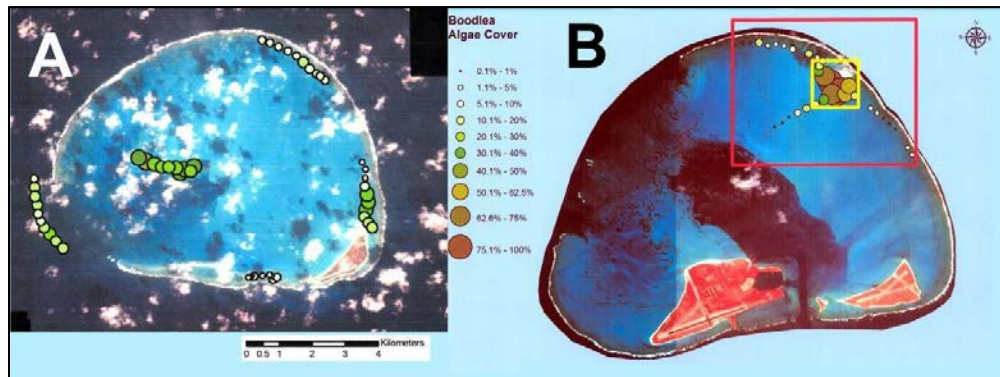
Figure 24. Scope/extent of *Boodlea composita* growth at Midway and Kure Atolls, 2008 (Vroom et al., 2009).

The documentation of singular, unusual features during towed-diver surveys have included coral species range extensions (Asher et al. 2012), and the documentation of large *Porites* colonies, including some thought to be the oldest on the planet (Brown et al. 2009).

Divers also note the presence of *Porites* colonies > 3-m diameter/height, and any unusual benthic features (e.g. species that look "out of place") in the "Comments" section, along with a time of sighting, approximate depth, and voucher photograph(s) if possible. In terms of importance, these data represent secondary priority to the benthic/macroinvertebrate tallies previously described.

Metadata (Towed-diver Survey Team Field Log)

The following information is recorded on the 'Tow Team Field Log' (Fig. 25) at the completion of the dive day and is entered into the database.

- **Local Date**: The date at the current location.

- **Island**: The island or atoll being surveyed, using the three-letter island code (e.g. Swains Island = SWA, Pearl and Hermes Reef = PHR, etc.).

- **Dive #**: The cumulative dive/survey number of the day. Daily dive operations typically range from 4 to 6 dives per day.

- **Tow type**: Normal for a regular tow, Benthic for benthic calibration, Fish for fish calibration

- **Divers Initials**: The initials of the towed divers.

- **Card. Direct.:** The cardinal direction of the tow, relative to the island (N, E, SW, etc.)

- **Garmin 78:** The assigned number of the GPS used to record tracks

- **Benthic Cam:** Indicates whether a benthic camera was used and was working properly (Y or N)

- **Cam Type:** The camera model used for the benthic camera (e.g. D7100)

- **Photos:** The total number of photos that the benthic camera recorded

- **Fish Cam:** Indicates whether a fish video camera was used and was working properly (Y or N)

- **Cam Type:** The camcorder model used for the Fish Video (e.g. GoPro Hero 4)

- **Benthic Seabird:** Indicates whether a Seabird Instruments temperature/depth logger was used on the benthic towboard and was working properly (Y or N)

- **Fish Seabird:** Indicates whether a Seabird Instruments temperature/depth logger was used on the fish towboard and was working properly (Y or N)

- **# Seg. If < 10** Fish/Ben: The number of segments for which data was taken, if not all ten segments were recorded.

- **Field Notes**: Any relevant notes related to the GPS or optical data collection, significant observations that occurred during the towed-diver survey, whether dive and ocean conditions were contributory to a less-than-perfect data collection effort or if there were any other survey issues.

- **Track processing notes**: The initials of whoever performed track processing, and any relevant issues related to track processing. For example, the standard tow line length for most towed-diver surveys is 60 m. However, tow line lengths may be shortened in shallower depths (e.g. backreef/lagoon surveys can use anywhere between 10 and 30 m lines). This should be noted in the metadata, as changes in tow line length play a role in determining track line layback (see Appendix F). It also should be noted if there were any problems/gaps in the track data or with the waypoints.

Figure 25. Tow team field-log excerpt.

Survey track processing

At the end of each field day, the survey track file is downloaded from the primary Garmin GPSMAP 78/78s and imported into an ArcGIS™ 10 Geodatabase using a custom built Python™ script to process the data. Temperature/depth data are downloaded from the SBE39 temperature and depth logger and are merged with the track points (see Appendix F). After the temperature/depth data have been added, layback calculations are used to create a file showing an accurate track of the divers, whose actual location is a distance behind the small boat. A unique serial number for each survey and survey segment is also created. These are created using a concatenation of the Year, Month, Date, and Dive; or Dive + Segment number (e.g. dive 1 on 9/25/07 = 200709251). These serial numbers allow for the translation of the 5-second point track file into line files based on either survey or segment. They are also the basis for the join between the fish or benthic data and the geodatabase which allows these data to be mapped to a specific geographic location (Richards et al. 2011). SBE39 temperature and depth loggers and GPS units must have their logs cleared prior to the next day's towed-diver surveys, after confirming that the layback algorithm has processed correctly by visually assessing the track lines.

Table 2. Historical changes to towed-diver methodology and equipment.

2000–2002	Benthic imagery collected from downward facing video camera.
2000–2007	Fish measurements collected by binning fish sizes as the following: > 50, > 75, > 100, > 150, > 200, > 250 and > 300 cm.
2000–2007	Quantitative & meta data recorded in Excel spreadsheets.
2002–2007	ArcView Avenue layback script created and used for track processing.
2003–Present	Benthic imagery collected via still camera.
2007–Present	Meta and field data sheet updated and logged concurrently.
2007–2009	Addition of > 25 cm of key vulnerable fish species (CHUD, BOMU) recording on and off transect during surveys.
2008–Present	Transition from mini-DV to DVD to QuickTime media storage for forward facing videos including archived imagery.
2008–Present	Fish & Benthic Towed-diver Survey (TDS). Access databases created for quantitative and observation data recording.
2009	Quality check of quantitative fish TDS Access database completed.
2009–2012	Transition of track processing scripts from ArcView Avenue to ArcGIS python.
2009–Present	Addition of all sizes for key vulnerable fish species (CHUD, BOMU) & protected species recording on and off transect during surveys. Added EPLA in 2012.
2011–2015	TDS benthic image data sets analyzed via Coral Point Count to augment per-island percent coral cover metric as defined in revised CRCP monitoring plan.
2011–Present	Forward facing Mini-DV camcorders replaced with HD digital cameras.
2012–2017	Added logging GPS position data via Trimble hand-held computer to improve resolution and add position quality (e.g. HDOP) and SAFEBoat® fish-finder depth data to position points. Updated to Furuno console mounted GPS unit in 2017.

2012–Present	ArcGIS python script updated to enable processing of GPS position data collected via Trimble hand-held computer & SAFEBoat® fish finder depth data.
2014–Present	Benthic tow data sheet revised: "rubble" was eliminated, "sand" data is collected only if greater than 50%, 'stressed hard coral' data is collected only if greater than 10% & 'sea cucumbers' have been eliminated.
2014–Present	Benthic tow camera change: moved to Nikon D7100 w/Ikelite housing (incorporated integrated strobe system).
2016–Present	Data sets incorporated into Oracle Database for archive and active analysis while Access Database remains field entry front end.
2017–Present	Supplemental logging GPS position data updated from Trimble to Furuno GP-1870F console mounted GPS unit.
2017	Quality check of integrated meta, quantitative and observation TDS data sets completed for Public Access to Research Results (PARR) implementation.

FIELD PREPARATION AND PROCESSING – TOW EQUIPMENT

Appendix A1: Benthic Pre-dive Preparations for Nikon D7100 Camera

Before leaving the ship, synchronize watches on both towboards to local time. Ensure cameras, watches, data loggers, temperature/depth logger, pencils, data sheets, towboards and lines, telegraphs, and all personal gear are in working order and on the small boat.

Camera Strobes (DS 51)

Install charged AA batteries in four strobes. Keep battery port area dry. O-rings should not be greased but checked for dust, lint, etc. and clean as needed. Hand-tighten the battery compartment screw, then add an extra half turn with a flathead screw driver. Strobes may last for five towed-diver surveys; however, it's recommended that strobes be switched after the third towed-diver survey.

Camera Preparation

Cameras should be synchronized to Coordinated Universal (UTC) time, which can generally be found on board the research vessel.

Nikon D7100 Camera Settings

     a. Lens Settings
        i. Set focus switch on *Lens* to M/**A**
        ii. Set focus dial on *Camera Body* to **AF**
        iii. Set main shooting mode dial to **M**
        iv. Set secondary shooting mode dial to **S** (Single)
     b. Menu Settings
        i. Autofocus settings
           1. Top screen is in **AF-C** mode*

* To change, push AF button and spin finger wheel on back of camera body (main command dial)

           2. Set top screen autofocus symbol to 'Auto'
              a. To change, push AF button and spin front finger wheel (sub-command dial)
        ii. ISO sensitivity settings:

Menu ❼ Shooting Menu ❼ ISO sensitivity settings:

              a. ISO Sensitivity = anywhere between 160 & 320
                  1. This will change during the dive depending on ambient conditions. While towing:

** if photos are dark, increase ISO

** if photos are light, decrease ISO

        b. Auto ISO Sensitivity control = **OFF**
     iii. Shutter speed
a. Set to 1/250 s
     iv. File settings
        1. Menu ❼ Shooting Menu ❼ Image quality ❼ **JPEG normal**
     v. White balance: Auto
        1. Menu ❼ Shooting Menu ❼White Balance❼Auto
     vi. Metering
1. Set top screen metering symbol to 'Center-Weighted'
        a. To change push FORMAT button on top of camera body and spin main command dial
     vii. Aperture
        1. Set to 6.3
     viii. Interval timer settings
        1. Menu ❼ Shooting Menu ❼ Interval timer shooting
        2. Choose start time ❼ **Now**
        3. Interval ❼ **00:00':15"**
        4. Select interval x no. of shots ❼ **999x1=0999****
        5. Start ❼ **On***

*turn the interval shooting on before you start the survey

* stop the interval timer by powering off the camera

     c. Strobe settings
i. Settings for strobes
        1. During dive, turn strobes on to 'TTL'
     ii. Settings for housing
1. Ensure the switch on the camera mounting plate of the housing is set to DS 50-51
2. Set strobe dial on outer part of underwater housing door to 'TTL'

Loading Camera into the Benthic Housing

1. At the beginning of each cruise, install the dome port onto the underwater housing. Replace the dome port O-ring if it has stretched out or shows signs of damage. The port opening on the housing has 4 port locks. Lift up on the release button of each port lock and slide the locks away from the port opening. Check to see that the O-ring is clean and lubricated (use Ikelite O-ring lube), and is properly positioned on the lip of the dome port. Grease the O-ring every 10 days. Once the dome port is secured to the housing, slide each port lock toward the port until each lock fully engages. ***Visually inspect the port locks to ensure that they have been properly locked into position, otherwise the camera risks becoming flooded!***
2. Secure camera body to mounting plate and ensure that a fully charged battery and 16+ GB memory flash card are installed. Ensure that previous images have been erased from the memory flash card.
3. Check the O-ring along the back door for dirt/grime/damage, making sure to grease O-rings every 1 – 2 days (use Ikelite O-ring lube) and ensure that the O-ring is seated in the groove. Replace the O-ring if it has stretched out or has damage. Place the back cover on the housing,

and close alternating clasps simultaneously (3 total). ***Ensure the main O-ring is properly seated in the door-channel and clasps are locked in position, otherwise the camera risks flooding!***

4. Attach strobes and strobe cord to housing and test the camera functioning with the strobes. Mount camera on the towboard.
5. Mount strobes and secure the cords to the housing cage but take care to not trap bridle lines.
6. Ensure that the protective cover is on the dome port, which will be used to protect the dome port when moving the camera in/out of the vessel, and during transport. Remove the cover prior to diving.

Appendix A2: Benthic Data entry, Quality Control Measures

Once data collection is complete and all divers are aboard the ship, all data sheets should be rinsed with fresh water and dried, in preparation for data entry. Divers enter their data into the benthic towed-diver Microsoft Access database "BenthicTeamDataEntry" that is stored on the ship's data server (e.g. T:\Cruise\CruiseData\ HA1201_Leg1\Database\ BenthicTeamDataEntry).

Initial data entry and quality control are the responsibility of the diver who collected the data. Quality control should include error checking the entered data against the data sheet after data entry. Data will also be cross-checked, with one benthic tow team member reviewing the entries made by their respective partner(s), once data for all sites surveyed that day have been entered.

These initial quality control measures should be completed after data entry each day. If errors are found, the database should be corrected to reflect the data on the data sheet.

Outside of regular data-checks, a system of ongoing quality control should be enacted in order to obtain the most precise and unbiased data estimates. This can be done through calibration dives (i.e. two benthic divers surveying the same swath), with approximately 5–10% of survey effort being targeted for calibration so inter-calibration coefficients can be calculated.

Scatter plots of each observer vs. every other observer for each variable will highlight consistent over- or underestimation by individual observers, which will be noted as systematic departures from identity on plots (Fig. 26).
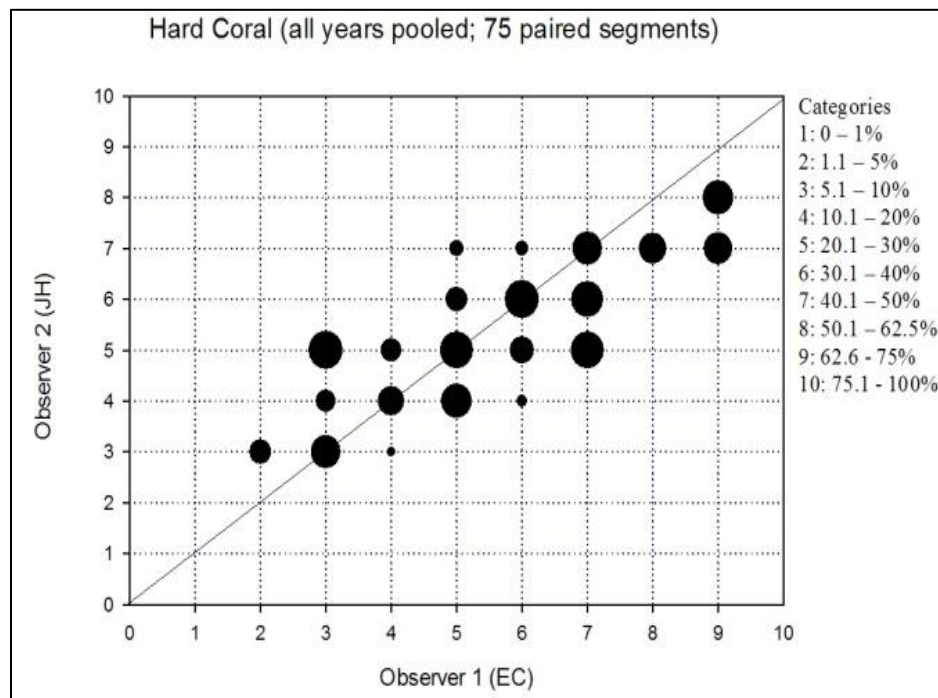

Figure 26. Example of hard coral inter-observer plot.

Comparing photo and observer data on a regular basis should help ensure that biases of all observers' estimates are minimized. Quantifying the absolute difference between observers for each variable will help to show if data precision could be improved by increased training or

practice. Generally, observers should agree within 1 category bin for all observations. If there is greater variation additional training and discussion should be initiated to determine the source of the imprecision.

Appendix A3: Benthic Photographic Downloading, Renaming, and Storage Protocol

Photographs collected during towed-diver surveys are downloaded each day from the camera's memory card to the T drive/server. There are approximately 200 photographs per tow. The memory card can be copied either by: 1) removing the memory card from the camera and placing it into the pistol-shaped memory card converter that attaches to a laptop via a USB connector, or 2) using the camera's connector cable to connect the camera directly to a laptop. All images should first be downloaded to a "Camera Download" folder that is designed as a repository for all images taken on the cruise (e.g. T:\Cruise\CruiseData\HA1701_Marianas\CameraDownload). From that folder, copy images to the appropriate folders in the "Optical" folder (e.g. T:\Cruise\CruiseData\HA1701_Marianas\Optical\GUA\TOW\BENTHIC). See examples from the MARAMP 2017 cruise directory below.

1) Copy and paste all images from the memory card onto the server:

T:\Cruise\CruiseData\HA1701_Marianas\ CameraDownload\ISLANDCODE\TOW\BENTHIC\ CAMERA-ID\MM-DD-YYYY\FI_LASTNAME

Example:

T:\Cruise\CruiseData\HA1701 Marianas\CameraDownload\GUA\TOW\BENTHIC\ NIKON_D7100\05-04-2017

These images are left in this folder in their 'raw' form and are back-up images.

2) Navigate to the following directory:

T:\Cruise\CruiseData\HA1701_Marianas\Optical\ISLANDCODE\TOW\BENTHIC\ ISLANDCODEmmddyy_TOW#

Create separate folders for each tow completed that day, using the naming convention:

ISLANDCODEmmddyy_TOW# (ie- GUA050617_1, GUA050617_2, etc.)

3) Images are then copied into their respective folders and sorted using the photographic timestamps to determine where the start/end of each survey falls.

E.g.: Photographs from six towed-diver surveys collected on May 5 around Guam would be sorted into folders: GUA050517_1, GUA050517_2, GUA050517_3, GUA050517_4, GUA050517_5, and GUA050517_6.

- Rename all the photos at the end of each day in one batch process using Bulk Rename Utility (see screenshot settings below for renaming. The benthic towed-diver survey photos are renamed in sequence according to location, date, tow survey number, and photographic number:
  - Location: Three Letter Island Code (E.g. Guam=GUA);
  - Date: Day/Month/Year (e.g. May 5, 2017 would be recorded as 050517);
  - Tow #: 1 – 6 (labeled as _1_, _2_, etc.)
  - Three-digit photograph # (typically 200 per survey, to be labeled as 001 to 200)

E.g.: GUA050517_1_001, GUA050517_1_002, GUA050517_1_003, … GUA050517_1_200.

NOTE: The total number of photos taken during each towed-diver survey will be recorded under 'Photo Count' in the database (initial screen of Quantitative Observations)

Appendix A4: Benthic Database Data Entry

Navigate to the Access database portal (Fig. 27) located on the cruise server. An example of the pathway would be: T:\Cruise\CruiseData\HA1401 Marianas\Database\BenthicTeamDataEntry.mdb

Click on the right-hand macro button marked "Benthic tow".

Several buttons appear. These are: a) Quantitative Observations, b) Qualitative Observations, c) Tow Descriptions, d) Data Export, and e) Data QC.

Begin data entry with the Quantitative Observations (Fig. 28 & 29). This represents the metadata entry portal for the towed-diver survey, and is often filled out by a member of the fish towed-diver survey team. However, all team members participating in cruise towed-diver surveys are equally responsible in ensuring that these fields are completed accurately.

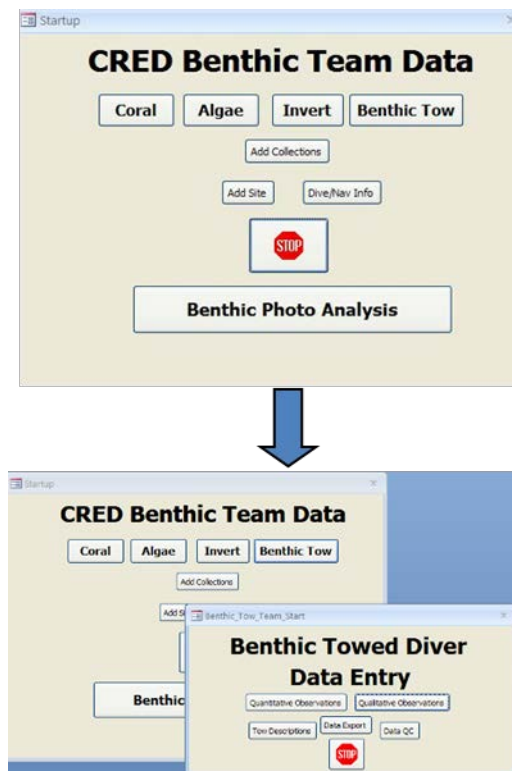The data manager for the cruise will format the Region, Year, and Islands list.

Figure 27. Benthic towed-diver team, initial database portal.

Metadata:

Date: Enter the Day/Month/Year

Dive #: Enter the sequential dive #, typically up to 6/day.

After entering Date/Dive #, an automatic DiveID number will be generated.

Tow Type: Enter "Normal" for a regular towed-diver survey, "Benthic Cal" for benthic calibration surveys, or "Fish Cal" for fish calibration surveys.

Diver1:: Enter the 2 – 3 letter code for the fish diver involved with that particular dive. The fish diver is always Diver1.

Diver2: Enter the 2 – 3 letter code for the benthic diver involved with that particular dive.

Figure 28. Initial screen of Quantitative Observations form (first half).

Cardinal Location/Direction: Enter the general location (i.e. side of island/atoll) where the survey was completed (North, East, Southeast, etc.)

Reef Zone: Enter forereef, backreef, or lagoon, depending on the zone surveyed. A fourth choice "unspecified" can be used in areas that do not fit the standard description of the previous three (e.g. surveys along the western shelf of Palmyra atoll)

Viz (m): Enter the average visibility in meters (typically entered from the fish towed-diver data).

Gap in/No GPS data: Leave unchecked if all GPS operations occurred normally. Check the box if a problem with the Garmin 76 or 76 Map arises that results in a gap in the survey trackfile or missing GPS data (e.g. if the batteries run out/unit turns off in the middle of a survey).

Benthic Camera: Check if camera was used during tow

Camera: Indicate which camera type was used (e.g. Nikon D7100)

 # Photos: The number of photos taken during a towed-diver survey (normally ~ 200).
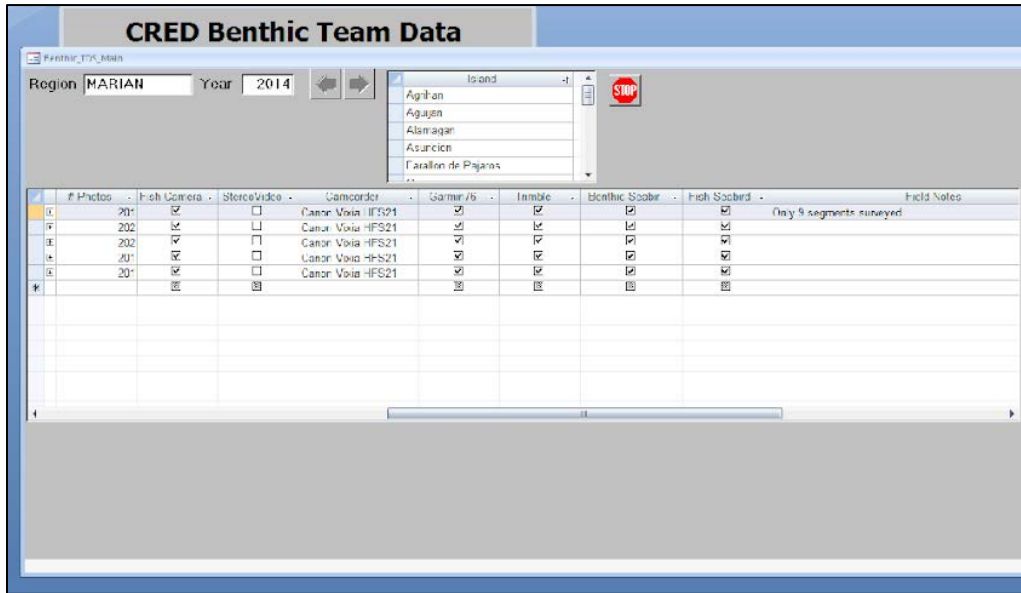
Figure 29. Initial screen of Quantitative Observations form (second half).

Fish Camera, Stereo Video & Camcorder Type: (will be entered by fish diver)

Garmin78: Check if a Garmin 78 GPS unit was used.

Trimble: Check if a Trimble unit was used (currently replaced by the Furuno chartplotter).

Benthic Seabird: Check if a Seabird Instruments SBE39 (or equivalent) was used.

Fish Seabird: Check if a Seabird Instruments SBE39 (or equivalent) was used.

Field Notes: Enter specific issues with equipment that may have occurred during the towed-diver survey. These can include camera operation problems (e.g. camera turning off, Error 99, poor image quality), and/or problems with the Seabird Instruments SBE39 (or equivalent) noted in GIS geoprocessing (e.g. not recording data due to battery disconnect). Reasons for shortened towed-diver surveys can also be listed here (e.g. due to diver recall, depth or environmental concerns, etc.)

Track Processing Notes: Enter any issues that may have occurred with tow tracks or waypoints during track processing (the Data Manager will indicate if there were any issues).

Survey specific data:

These data are entered from the Towboard Habitat Survey sheet (see Fig. 9). Click on the + sign next to the appropriate date in the DiveID column. This will bring up the data entry screen (Fig. 30):

Figure 30. Quantitative Observations entry form.

Note: if no data is within any specific towed-diver segment (e.g. from diver recalls, divers being too far above benthic strata, etc.), choose "NDR" from the dropdown "Habitat" menu. This represents "No Data Recorded" for that particular segment.

No Obs: leave unchecked.

Cal: Check if the dive was a benthic calibration dive.

Seg: Enter the time segment number (1, 2, 3, etc.).

Habitat: Enter the 2-letter benthic habitat code for that segment (e.g. CR, PV, etc.). If more than one habitat was recorded, then enter both codes (e.g. PR/RF).

Comp: Enter the complexity code (e.g. L, MH, H, etc.).

Coral: Enter the bin number recorded for Total Hard coral.

Stress: Enter the bin number recorded for Stressed Hard coral.

Soft: Enter the bin number recorded for Soft coral.

Sand: Enter the bin number recorded for Sand.

Malg: Enter the bin number recorded for Macroalgae.

Calg: Enter the bin number recorded for CCA.

Invertebrate data (INVERTS: COTS, Sea Urchins, Giant Clams.) that falls into a bin category (26–50 (Bin 1), 51–100 (Bin 2), etc.) should be converted using Table 3 and that

38

number entered into the database. For example, if COTS were a circled "1", "37" would be entered in the database under COTS for that segment. If the "1" was not circled, "1" would be entered, which would signify that only a single COTS was seen.

COTs: Enter the data entry conversion number corresponding to the bin number recorded for COTS.

F_Urc: Enter the data entry conversion number corresponding to the bin number recorded for Sea Urchins (Free)

B_Urc: Enter the data entry conversion number corresponding to the bin number recorded for Sea Urchins (Bor)

Clam: Enter the data entry conversion number corresponding to the bin number recorded for Giant Clams.

The following are marine debris categories that may have been recorded in the "COMMENTS" row on the data sheet.

Net: Enter the number recorded for any derelict fishing nets.

Amo: Enter the number recorded for munitions or unexploded ordnance.

Wreck: Enter the number recorded for shipwrecks or shipwreck debris.

Debris: Enter the number recorded for any miscellaneous debris.

DebrisNotes: Enter any specific information regarding debris seen.

Table 3. Invertebrate bin conversion table.

Range (Invert #)	Bin	Data Entry Conversion
26–50	1	37
51–100	2	75
101–250	3	175
251–500	4	375
501–1000	5	750
> 1000	6	1001

Appendix B1: Fish Tow Camcorder Prep & Operating Procedures

   Set Up/Break down: The ESD fish towed-diver team currently uses a GoPro Hero 3+ Silver or Hero 4 Black High-definition digital video camera with a battery 'bacpac' for extended battery life. The camera and bacpac can be charged separately via the mini-USB. Before taking the camera into the field each day, *ensure the camera settings are correct and the memory card is cleared and put back into the camera*.

Mode: Video

Video quality: 720 p or 1080 p (not 920 p—field of view not wide enough)

Frame Rate: 30 fps

Time: On UTC time synched to the second with watches

   Secure the camera in the housing in an air-conditioned room and do not open in the field. If it is necessary to open the housing in the field to change batteries (e.g., on days when a 6th tow is conducted), take as much care as possible to keep the camera protected from the elements (salt spray, etc.). Ensure the red filter is free of scratches and smudges and that it is securely fastened to the front of the camera. If a red filter does become scratched, replace it.

   Bring spare batteries and a spare GoPro into the field each day in a Pelican case as a backup. Prior to towing, attach the GoPro to the towboard via GoPro mount. For ease of use in the field 'One button' settings can be turned on so that the camera automatically begins recording in the preferred settings as soon as the camera is turned on and stops when the camera is turned off. To turn the camera on or off, hold down the button on the front of the camera. To start/stop recording, press the button on the top of the housing.

   Uploading: At the end of each day, remove the GoPro from the towboard and soak it in fresh water for about an hour and push all buttons. Dry the housing off and remove the camera from the housing. Plug the camera into a computer via mini-USB on the side of the camera. This will charge the batteries and allow video download. Once both camcorder and computer are connected, turn on the camera by holding down the button on the front of the camera.

   Uploading tow video to the server can cause the server to become very slow for others trying to enter data. To avoid causing them great frustration, first copy the video to an external hard drive and then transfer it to the server at a time when others are not using it (the following morning is a good time).

Create a folder to which to save the videos from the day. Use the file path:

[ExternalDrive]:\[Region]\[Island]\[IslandCodeMMDDYY]

Removable Disk D:\DCIM\###GOPRO\

Copy all video and paste it in the new folder on the external drive.

   Once video has been uploaded, navigate to the folder in which the files have been uploaded and check that all files have successfully uploaded.

Rename each video section to correspond to the tow on which it was recorded. Video files from a 50 minute tow are automatically broken into three files of ~2.2GB or less. The first file is automatically named GOPR#### with consecutive video files named GP01####, GP02####, etc. (#### are the same for each tow). Add numbers 1–6 at the beginning of each file corresponding to the tow number of the video (e.g. for the first tow of the day: 1GOPR5555, 1GP015555, 1GP025555)

The following morning copy the video from the external drive to the server. Create a folder to which to save the videos from the day. Use the file path:
T:\OPTICAL\[Region]\[Year]\[Island]\TOW\FISH\FORWARD\[IslandCodeMMDDYY]

Appendix B2: Fish Data Entry Procedures

    Data Entry: Rinse data sheets with fresh water and when dry, write over the penciled data with a permanent marker. Data is entered into the ESD Fish and Towed-diver database using Microsoft Access (Fig. B1). This is on the T: drive on the ship server, under T:\Cruise\CruiseData\[cruise prefix e.g. HA1201]\Database\Database security.
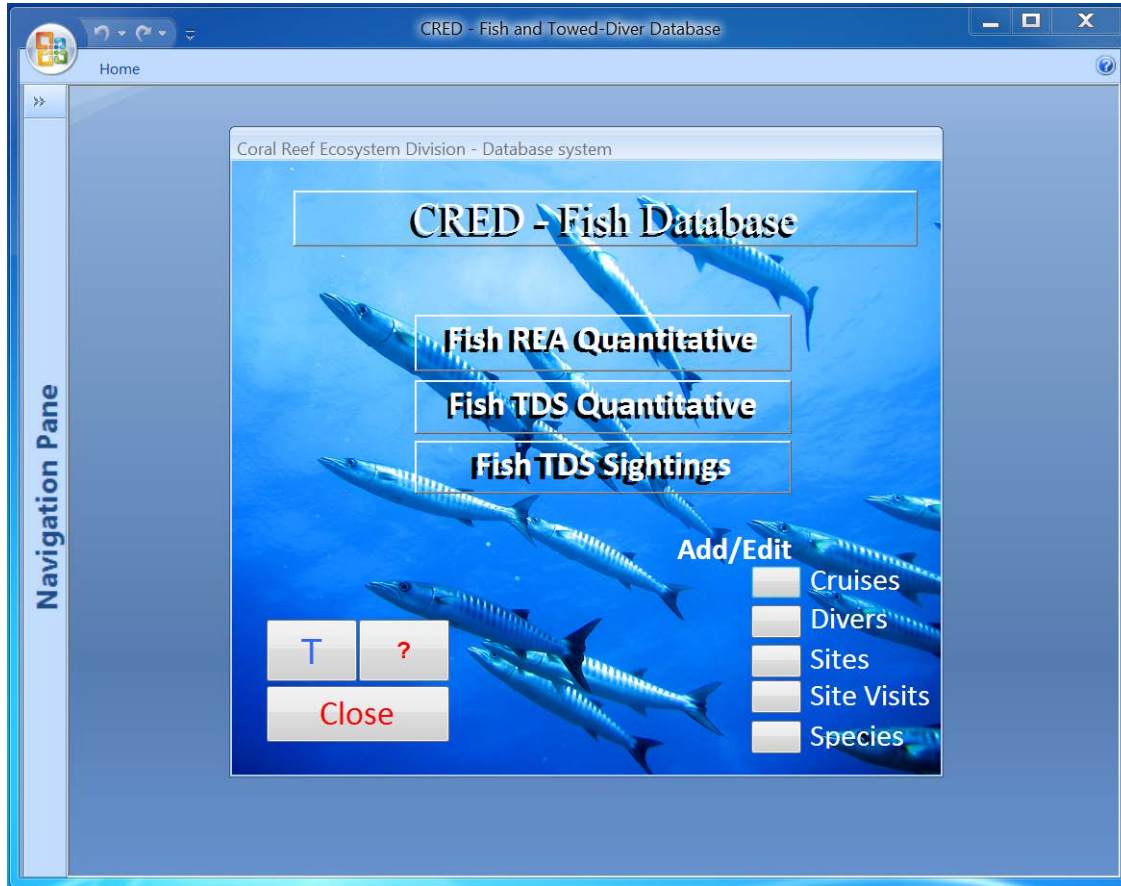
Figure 31. Microsoft Access fish towed-diver database interface.

    To enter quantitative data, click on the "Fish TDS Quantitative" button. On the next interface, select the appropriate region, year, and island from drop-down boxes on the entry form (Fig. 32, red arrow). On the next available line (Fig. 32, black arrow), enter the date the data was recorded, dive number (consecutive tow number for the day), diver initials, dive buddy's initials, average visibility, reef zone, cardinal location/direction, and tow type.

Reef Zone: Forereef: unprotected reef crest

                Backreef: protected area just inside the forereef

                Lagoon: protected area, but not backreef

                Unspecified: whatever does not fit into above descriptions

Cardinal Location/Direction: The side of the island that was tow surveyed.

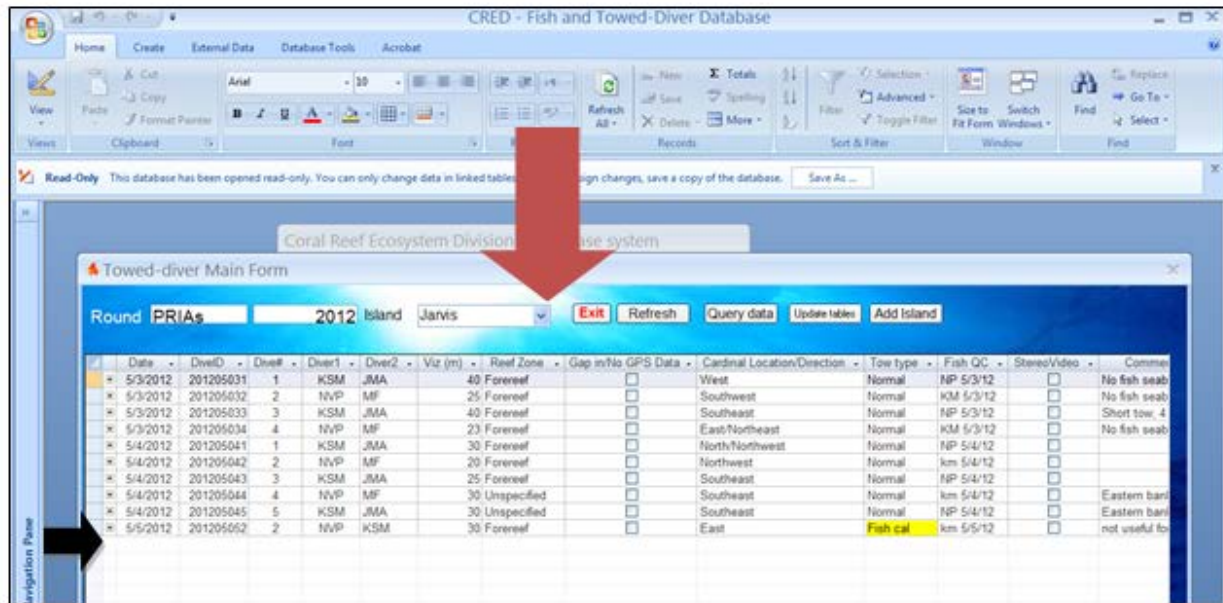**Tow type:** either "Normal" or "Fish cal" for fish calibration.

Figure 32. Quantitative data entry form.

To expand the selection and enter each fish record, click on the '+' sign next to the date. In this form, enter the segment number, species code, size, and count for each record (Fig. 33). There must be exactly 10 segments (1–10) entered for each tow. For segments with no recorded fish there must still be an entry of that segment with 'NONE' entered for species code. If no survey was conducted during a segment then an entry of that segment with 'NOSC' (No Score) must be entered for species code. The remaining fields will self-populate. Data is automatically saved, and the observer can click 'Exit' after entering data. When data entry is complete, the fish divers trade data sheets for data quality control (QC). Each diver opens the database and ensures the other diver's data was entered correctly. Upon completion, the observer who performed the QC adds their initials and date in the 'Fish QC' column next to 'Tow Type' for that dive.
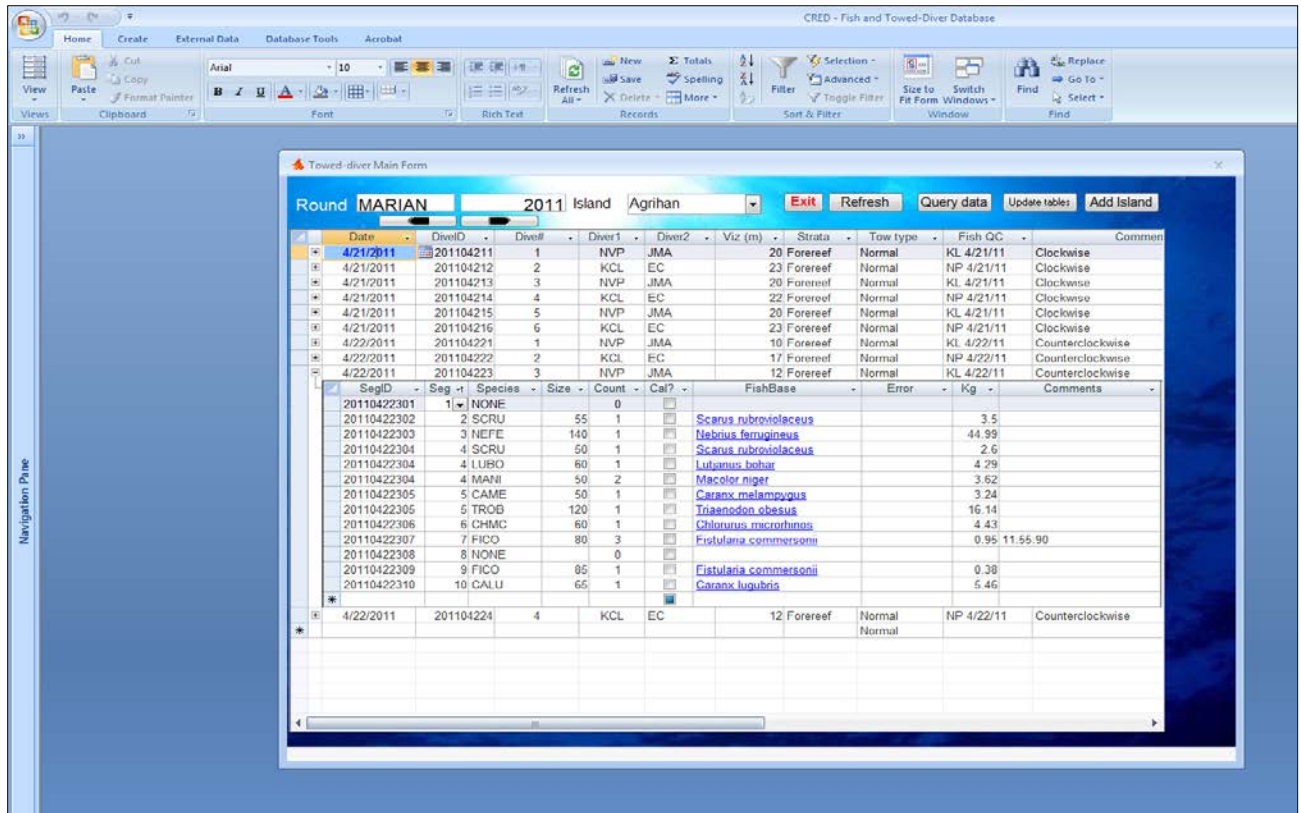
Figure 33. An exampe of size and count data for the dive.

To enter sightings data, observers will click on the "Fish TDS Sighting" button on the main menu. Divers then select the appropriate region, year, and island from the drop-down boxes on the entry form (Fig. 34, red arrow). The information on the dive has already been entered and should be generated on this page. Click on the '+' sign next to the date and enter each record with the appropriate Species (4-letter code or use the drop box), Segment, Size and Count. Under the Quality tab choose '100% certain' unless the observer is unsure or was not able to get a photo or video to verify. Record any specific details in the Notes tab. There is no requirement to enter every segment in this form, just those segments with a record.

After completing data entry and quality control, data sheets should be filed together with others from the cruise for future reference.
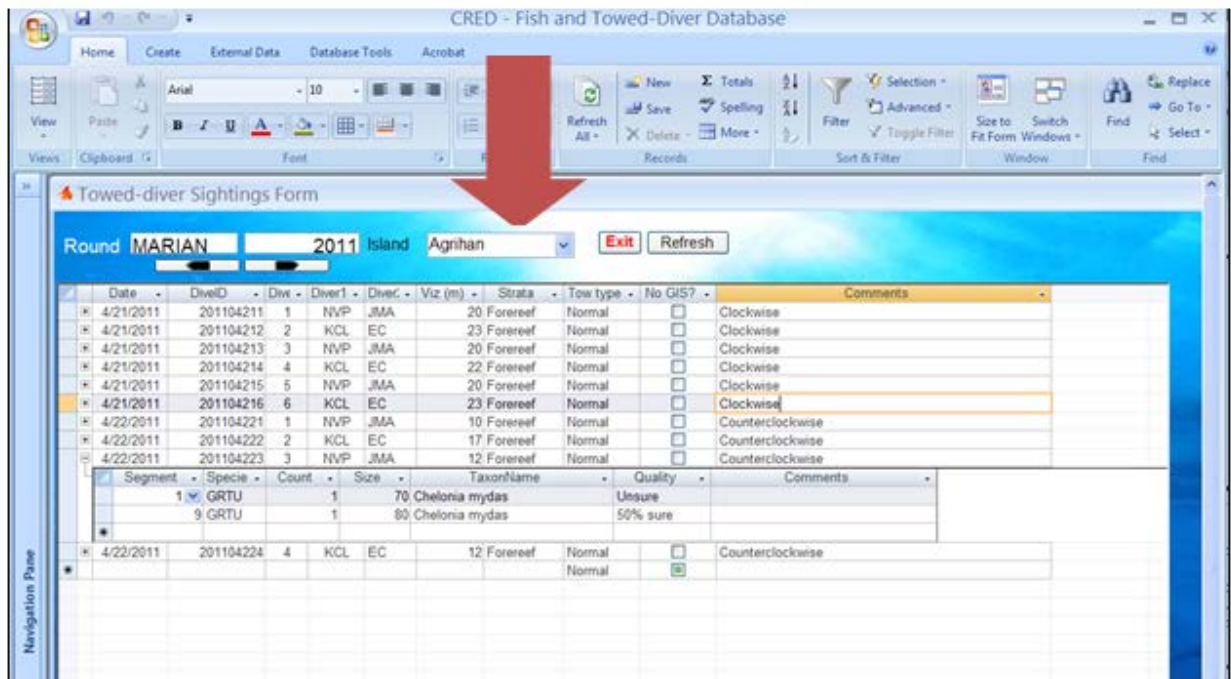
Figure 34. Sightings data entry form.

Appendix C: Configuring & Uploading Waypoints to the Small Boat GPS

   The Furuno GP-1870F is the **primary** GPS chartplotter used on the ESD small boats.
Configuring Furuno GP-1870F: (See Furuno manual for details: T:\Towboard\Manuals &
Instructions\ Furuno_GP1670F_1870F Operator's Manual ver F, beginning page 9-1).

   Necessary equipment:

- GPS Utility software
- A computer with SD card capability
- Furuno GP-1870F unit

   Unplug the transducer from the back of the GPS**.** If the transducer is running out of the water
it can burn up in as little as 20 minutes.

   Initialize SD card in GPS before using it (see manual)

   The GPS can read only PNT files which must be created using GPS Utility software. Up to
30,000 waypoints can be stored in the GPS. Points must be in a single PNT file as only one file
can be loaded on the GPS at a time. Create a single PNT file for all locations using 5–10 points
per segment of previous tows.

   See Section 9.7 in the manual for importing PNT files to GPS

Configuring alternate GPSMAP 3006C/3010C: This should only need to be done once unless
settings are reset.

Necessary equipment:
- DNRGPS, DNR Garmin or G7toWin software
- A computer with Serial Port (or use Keyspan adapter). **Note: Keyspan adapter is
  not recognized by G7toWin software & doesn't work. However, it does work with
  DNR Garmin & DNRGPS
- GPSMAP 3006C & PC connection cables

   For use with other Garmin devices (GPSMAP 178c, GPSMAP 740s, GPSMAP 520s) see:

   T: Drive\Towboard\Mapping\Trimble ESD-GPSDataCollection

From the Main Menu, select the *System* tab.

Select the *Comm* tab.

Highlight the *Port 1* field and press the *Enter* button.

Select *NMEA In/NMEA Out* and press the Enter button.

Press the *NMEA Setup* soft key to open the *Advanced NMEA Setup* page.

In the *Advanced NMEA Setup* window, ensure *GPRMC, GPGGA, PGRME, SDDBT, and SDMTW* are all selected. If any of those sentences are not selected, use the arrow button to move to/highlight the sentence type and press the *Enter* key to select.

In the *Advanced NMEA Setup* window, highlight the *Lat/Lon Minutes Precision* field and press the *Enter* button.

Select *XX.XXXX' (4 digits)* and press the *Enter* button.

Press the *Quit* button to exit these screens.

Uploading GPS points:

Turn on GPSMAP 3006C and connect the GPS to your computer by serial port

Open DNR Garmin (If not installed already, the software is saved at T:\GIS\tools\GPS Tools\dnrgarmin54setup.zip)

Open DNR Garmin Properties window by clicking File\General Properties… Under the Projection tab, make sure that the projection is set to be WGS84 (with no Projection)

Ensure that the GPS name shows up under the area below the main menu of the window. If the GPS is not properly connected, the following message will be generated (Fig. 35)
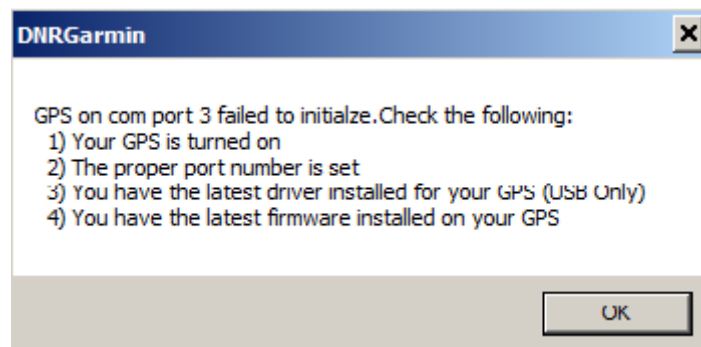
Figure 35. DNR Garmin menu window.

Click File\Load From\File… to start navigating to the GPS points (in DBF file format for this instruction). Ensure the file type is set to be Dbase IV (*.dbf)

Select the DBF file with the latitude and longitude and click Open

In Identify Fields dialog, choose a unique ID field for ident, Y field for lat, X field for long, and click OK.

Once all points are loaded to the software, upload the points to GPS by clicking Waypoint\Upload

If other sets of points need to be uploaded, click Edit\Empty Table to clear the records in the DNR Garmin, and repeat the steps 5 to 8

Click X to exit the DNR Garmin and unplug the GPSMAP 3006C.

Delete the points on GPSMAP 3006C:

Turn on GPSMAP 3006C

Press and hold ADJ/MENU key to open the main menu.

Select Points menu on left and select a point on the User sub tab.

   Select Delete to delete the selected waypoint, Select Delete All to delete all points on the unit.

Appendix D: GPS Waypoint/Track Download and Creating Dive Time Text File

The G7ToWin application is required for the computer and available online at http://www.gpsinformation.org/ronh/g7towin.htm or at T:\V-Drive\Towboard\Software and extensions.

GPSMAP 78 & 78s:

Note: download cable for 78 & 78s has USB connection (unlike GPSMAP 76 = only has serial cable connection)

Ensure the GPS is in serial interface mode: System > Interface > Garmin Serial

Plug the GPS into the computer using the mini-USB port on the Garmin and computer USB port. The GPS screen will become a USB icon.

In 'My Computer' navigate to the day's tracks and points at Garmin GPSMAP 78s D:\Garmin\GPX.

Open the day's waypoints with G7toWin. Navigate to File > Save as

Navigate to T:\Cruise\CruiseData\[Cruise ID]\\Project Group\Towboard\[ISLAND_NAME]\GPS Downloads

Using the bottom dropdown menu, select the file type Gardown (.gdn).

Save the file as wMMDDYY.txt (w for waypoints) for example: w140506.txt. *Add the .txt on the end of the file name.*

Once saved repeat steps 3–6 for tracks. When saving tracks, use a 't' instead of a 'w' at the beginning of the file name.

Navigate to the folder the waypoints and tracks were saved in and check that they have uploaded properly.

GPSMAP 76 & 76C:

Plug the GPS into the computer using the serial cable (Keyspan adapter is NOT recognized by software; must have direct plug-in connection).

Open G7ToWin.

Go to GPS>Download from GPS>Waypoints. It will take a moment to upload.

Navigate to T:\Cruise\CruiseData\[Cruise ID]\\Project Group\Towboard\[ISLAND_NAME]\GPS Downloads

Using the bottom dropdown menu, select the file type Gardown (.gdn).

Save the file as wmmddyy.txt (w for waypoints) for example: w140506.txt. *Add the .txt on the end of the file name.*

Once saved repeat steps 3–6 for tracks. When saving tracks use a 't' instead of a 'w' at the beginning of the file name.

Navigate to the folder the waypoints and tracks were saved in and check that they have uploaded properly.

Creating text file with dive start and end times: Create a metadata text file with the time zone and start and end times (as recorded in local time by the divers on their data sheet) for each of the towboard surveys conducted today. This is a simple text file where each line represents a tow and the start and end times and tow rope length, each separated by a space. Times should be expressed as hh:mm:ss. The end time is optional, if not provided it is defaulted to 0:50 after the start time. The line length is also optional, if not provided it is defaulted to 60 m.

For example:

tzOffset : -11

10:05:03 10:55:03 60

13:08:50 13:58:50

Name the file with the survey date (<mmddyy>.txt, 021210.txt) and save it in the proper directory on the data server (i.e. \CruiseData\<CruiseName>\Project Group\Towboard\<Island>\Dive Times).

Once the data manager has confirmed that the scripts were processed correctly (see Appendix F for script processing), delete the tracks on the GPS to make room for the following day.

Appendix E: Towboard Seabird 39 (SBE39) Downloading and Resetting

Connection: The nipple end of the Seabird connects to the computer. Unscrew and remove the black protective cup. Pull on the rubber end to pop out the casing. Four prongs should be visible (one is larger than the others). Attach the SBE download cable to your COMM port on your computer (Seabird cable is compatible and works with a Keyspan adapter). Insert the rubber end into the SBE. There is a black ball towards the base of the connector. Line this ball up with the large prong and snap into place. Now your SBE will be ready for downloading.

Downloading:

Open *SeaTerm* in programs under Sea-bird

Note: There may be an automatic prompt to configure the Seabird. If this happens select SBE39 from the drop-down menu and the correct COMM Port. The location of the linked port to the Seabird is found in 'Start'>'Computer' (right-click)>'Manage'>'Computer Management'>'Ports'. Administrative Rights for the computer are required to navigate here.

When *SeaTerm* is opened, go to *Configuration menu* and select SBE39. There will be an automatic prompt with *SBE Configurations Options* window

- Select the *Com settings* tab to ensure that the correct *COMM Port* is listed
- Select the *Upload Setting* tab to ensure that "All as a single file" is selected
- Select the *Header Information* tab to ensure that "Prompt for header information" is selected.

Once completed it is not necessary to repeat this step unless the program was used for another SBE instrument besides SBE39.

Select *Connect Box* with the computer image. At the prompt S> type in *Stop*.

Select the *Upload Box* with the file cabinet image

- The header prompt should pop up automatically
- Under comments identify and type in the following
    - Island/Atoll/Reef
    - Benthic or Fish Towboard
    - Cruise ID (e.g. HA-1606)
    - Date (local date, MM-DD-YY)
    - Initials of downloader
- There will a be prompt to direct the file to its location to be saved and for a file name. Label the files as follows:
    - File name = td(date)D (ex: *td021505D*) for a benthic board

= td(date)F (ex: *td021505F*) for a fish board

Once the information is downloaded, clear the contents and reset the Seabird. Reset the Seabird only after the Data Manager has indicated that tow track processing is complete with no errors.

Resetting: Towed divers need to ensure the date and time is set properly. Time must be in UTC format. If time and date are not correct change it by typing in the following commands (no spaces):

- *MMDDYY*=(the month, day, year, e.g. 021505)
- *HHMMSS*=(the hour, minute, second, e.g. 180506)

Note: The date must be typed in first, followed by the time.

Type in *ds* after the command prompt in order to check and view changes. The clock is running in real time so it will be off from what was originally entered.

Towed divers need to check and ensure that the sample number and time interval are set properly. The time interval must be set at 5 seconds and the sample number reset to 0.

- For the Time Interval type: *interval*=5
- For Sample Number type: *samplenum*=0

Type in *ds* after the command prompt in order to check and view changes.

Set the Seabird to start recording at the specific time and date the next tow. Type the following:

- For day type: *startmmddyy*=(month, day, year of next tow, ex:021605)
- For time type: *starthhmmss*=(hour,min,sec of tow, ex: 173005)

At command prompt type in *startlater* and press enter. This tells the SBE to start recording at the set delayed time.

Note: In the event of a timed-out, simply type in *ds* (display status)

Once everything has been reset, click on the *Disconnect Box* and proceed to remove the downloading cable from the computer and SBE. Reinsert the rubber nipple onto the SBE by lining up the 2 black holes with the large prong and finally screw back on the black protector.

Changing Batteries: The SBE39 uses a 9-volt (9V) battery. Alkaline batteries are used instead of rechargeables as they do not need to be changed often. One 9V alkaline battery can last for an entire cruise (~3 months). Check the battery voltage in SeaTerm by typing 'ds'. Change the battery if the voltage drops below 7.1 V. To change the battery, unscrew the protective white casing around the center. Once removed, use a crescent wrench to unscrew the metal back end. When completed, slowly pull out the insertion and carefully replace the existing battery with a new one. Replace the desiccant pack. Screw back on the metal back-end, tighten it with a crescent wrench, and screw back on the sensor protective covering.

Appendix F: Instructions for Processing Towed-diver Survey Tracks

CRUISE DATA MANAGER

Processing ESD towed-diver survey tracks is currently the responsibility of the Data Manager.

Notes:

- These instructions are for the use of Towboard Scripts v 7.0
- These instructions are for processing of Garmin GPSMAP 76/78 GPS & SBE38 temperature/depth units.
- Detailed README files and examples of each file type used in track processing can be found at:
    - (Cruise Server)\Software & Extensions\Towboard track processing scripts\sample-data\

SETUP

Installation of Towboard Scripts 7.0 ArcGIS Toolbox

- If the <Towboard Scripts> ArcToolbox is already installed on the computer, skip these steps below and move on to step 9.
- Copy <Towboard.zip> Arc Toolbox from T drive or \\PicMakai\Towboard\Software & Extensions\ to the desktop (or directory of your choice) of local computer.
- Extract the files to a designated folder. A new folder will be created call <towboard>. This folder contains the Towboard ArcGIS toolbox, scripts, and sample data.
- Start ArcMap
- Open the ArcToolbox pane if it is not already open
- Right-click and choose <Add Toolbox...>
- Navigate to the <towboard\toolboxes> folder from Step 2.
- The <Towboard Scripts> toolbox should now appear in your ArcToolboxes list.
- Right-click in an empty section of the ArcToolbox pane and select <Save Settings> and choose <To Default>
    - This will ensure that the Towboard Scripts toolbox loads each time ArcMap is started.

CREATING TOWBOARD GEODATABASE

If a cruise Geodatabase has already been established, omit these steps below.

- Open <Towboard Scripts> toolbox by clicking on the <+>
- Creating Geodatabase
- Double-click <Initialize databases>
- Select an output folder (on local computer or the dataserver) where the Geodatabase will be stored.
- There will be 1 Geodatabase for each leg of the cruise.
    - All of these should be stored in the same folder.
- Name the Geodatabase as <CruiseID>_Leg<#>_Towboard_GIS.
    - (i.e. HA1401_Leg1_Towboard_GIS)
- Click <OK> The script will create the database (~3 min)

TOW TEAM MEMBERS

The Tow Team is only responsible for steps listed below. See Appendices D and E.

Downloading and Renaming the Input Files:

Notes:

- A data manager will check if the input files are saved in proper directories with proper naming conventions.
- The data manager also checks to see metadata texts correspond to field log sheets, and tzOffset is set to be right time zone.

Steps Garmin GPS76/78:

- Download Garmin GPS76/78 unit used to record towboard track information using G7toWin.
- Download and save the track information as a Gardown file (.gdn) file in the proper directory on the data server
  - (i.e. \CruiseData\<CruiseName>\Project Group\Towboard\<Island>\GPS Downloads).
- Name the file with "t" and survey date and change the .gdn extension to .txt (t<mmddyy>.txt, i.e.t021010.txt).
  - This is the same method used in previous years and outlined in the blue towboard 3-ring binder.

Steps SeaBird SBE39 (or equivalent) units:

- Download "Fish" and "Benthic" SeaBird SBE39 units using SeaTerm.
- Save Seabird SBE39 information as .asc file in the proper directory on the data server
  - \CruiseData\<CruiseName>\Project Group\Towboard\<Island>\Seabirds).
- Name the file with "td", the survey date and "D" or "F" to distinguish the files (td<mmddyy><D/F>.asc, i.e. td021210F.asc).
  - This is the same method used in previous years and outlined in the blue towboard 3-ring binder.

Create Metadata Time File:

- Create a metadata text file with the time zone and start and end times (as recorded in local time by the divers on their data sheet) for each of the towboard surveys conducted today.
- This is a simple text file where each line represents a tow and the start and end times and tow rope length, each separated by a space.
- Times should be expressed as hh:mm:ss. The end time is optional, if not provided it is defaulted to 0:50 after the start time. The line length is also optional, if not provided it is defaulted to 60m.
  - For example:

    tzOffset : -11

    10:05:03 10:55:03 25

    13:08:50 13:58:50

- Name the file with the survey date (<mmddyy>.txt, 021210.txt) and save it in the proper directory on the data server
  - (i.e. \CruiseData\<CruiseName>\Project Group\Towboard\<Island>\Dive Times).

CRUISE DATA MANAGER

Loading data into Geodatabase:

Notes:

- To be completed when the Tow Team is finished downloading and have created the DiveTime files.
- All input data files can be found in subdirectories of
  - T:\Cruise\CruiseData\[CruiseDirectory]\ProjectGroup\Towboard\[IslandCode]\
- Use ArcGIS template under:
  - T:\Cruise\CruiseData\[CruiseDirectory]\GIS\ArcProjects\ CruiseNumber_Tow_QC.mxd

Steps to Load Data:

- Click on 'Load Data' tool (in ARCToolbox\Towboardscripts7.0\) and fill out as below (using the pertinent cruise directory and Island code)
- Under Select survey start/stop time file box, navigate to the time text file
- Under Select GPS track file, navigate to the GPS track file
- Navigate to the Benthic and Fish SeaBird files.
  - SeaBird SBE39 data is optional.
  - If the SeaBird SBE39s did not function, leave these fields blank.
  - If the start of the Seabird SBE39 timestamp is later than the start time of the survey, the script might not run.
- Leave Select NMEA log file (optional) box blank.
- Leave Select folder with benthic photos (optional) box blank.
- Enter the appropriate metadata

- o Enter cruise ID (e.g. HA1007)
- o Enter region CODE using standard 4 letter format:
  - ▪ NWHI, MNHI, PRIA, CNMI, AMSM
- o Enter appropriate Island CODE using standard 3 letter format
  - ▪ (i.e. FFS, PHR, MID, etc)
- o Enter small vessel name (optional) choosing from three options:
  - ▪ SAFEBoat^{TM} Vessel, RUBBER DUCK, STEEL TOE
- o Enter console GPS model (optional) choosing from four options:
  - ▪ GPSMAP 178c, GPSMAP 520s, GPSMAP 3006c, GPSMAP 740s
- o Enter initials from diver database

Figure 36. 'Load Data' prompt screen.

- Click on Environments… button and navigate to the current Towboard GIS database:
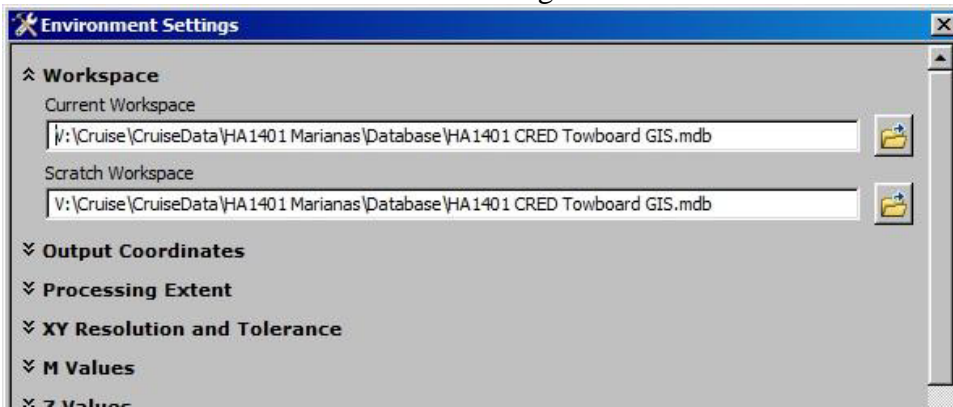
Figure 37. Setting the workig database prompt screen.

- Click OK twice to start the script, status window will say 'Complete' if script runs successfully.
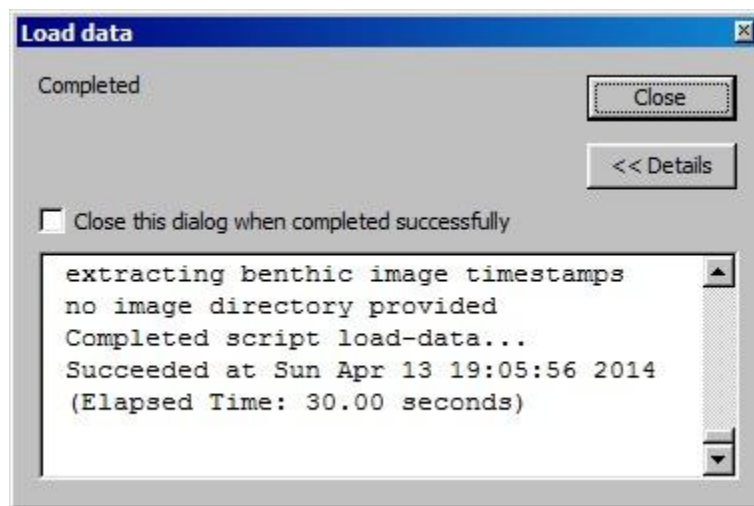
Figure 38. Successful 'Completed' script processing screen.

- If an error arises, consult with Tow Team Lead to correct input files.
- If the error cannot be corrected, make a note in the Tow Field Data Sheet.
- Track processing transcript will get written in Tow track processing transcripts folder where the input files locate

Visual QA/QC:

- QA/QC before nightly meeting
- Visually QC the Tows, Open ARCGIS and visually inspect the tow routes.
- Ensure all tows for the day are represented.
- Zoom into the area (or island) where the survey has been done. Double-check to ensure the tracks for the day are displayed in the correct location.
    - If not, ensure in the track processing transcript to see the input files from correct date have been used.

57
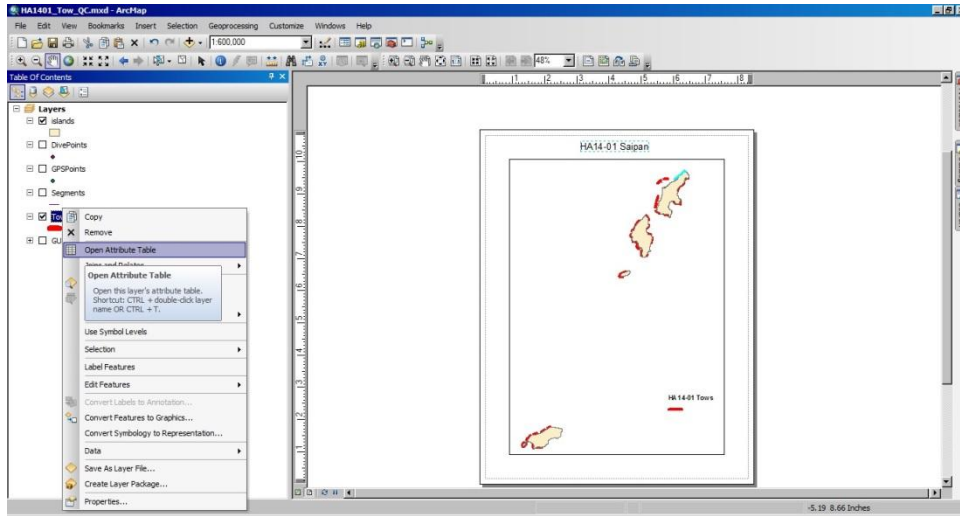
Figure 39. ARCGIS working project screen.

Generate Statistics:

- To generate statistics, right-click the Tows Layer and select "Open Attribute Table"
- Find and highlight todays tows
    - Navigate over to the ComputedLength Column
    - Ensure there is correct number of dives.
    - Right-click on the <ComputedLength> column and choose <Statistics> and report the statistics to Tow Team Lead.
- This will display the cumulative number of dives as well as their min, max, sum, and mean length in meters.

Figure 40. ARCGIS attributes table for a working project screen.

The important items to note from the statistics are:

● Count = # of Tows
● Minimum and Maximum are Min and Max length in meters – Fig. 41 shows Min as 1.8Km and Max as 2.5km
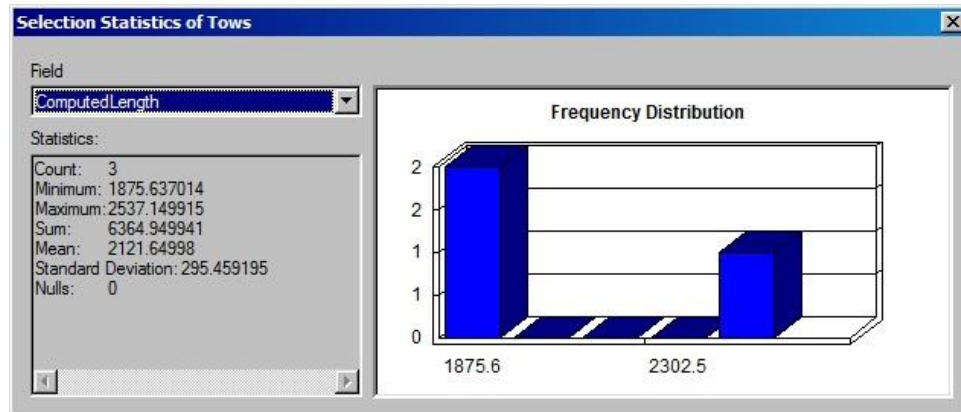● Sum = Total length of tows conducted today – Fig. 41 shows 6.3km

Figure 41. Statistics report screen.

If Desired, Create a record of the statistics by (on a windows computer):

● Clicking on the static graphic
● Click Alt-Prnt Scrn (to get to the Print Screen button, press Fn-Alt-PrntScrn)
● Open the Paint Program (Start/All Programs/Accessories/Paint)
● Click on the new palette that opens and press Ctrl-V (or right-click on the palette and select "Paste")
● Select the Text Tool (the [A] button) and add the Cruise ID, the word Tows, the Island Code, and Date (not shown). If the graphic was correctly labeled, it would read **"HA14-01 Tows (SAI) 4-13-2014"**
● Save the graphic as a .jpg to the [Cruise Directory]\Project Group\Towboard\[Island Code]\Daily Stats directory in the form of YY-MM-DD.jpg .
● The Case of the Example would be saved as: T:\Cruise\CruiseData\HA1401 Marianas\Project Group\Towboard\SAI\DailyStats\14-04-13.jpg
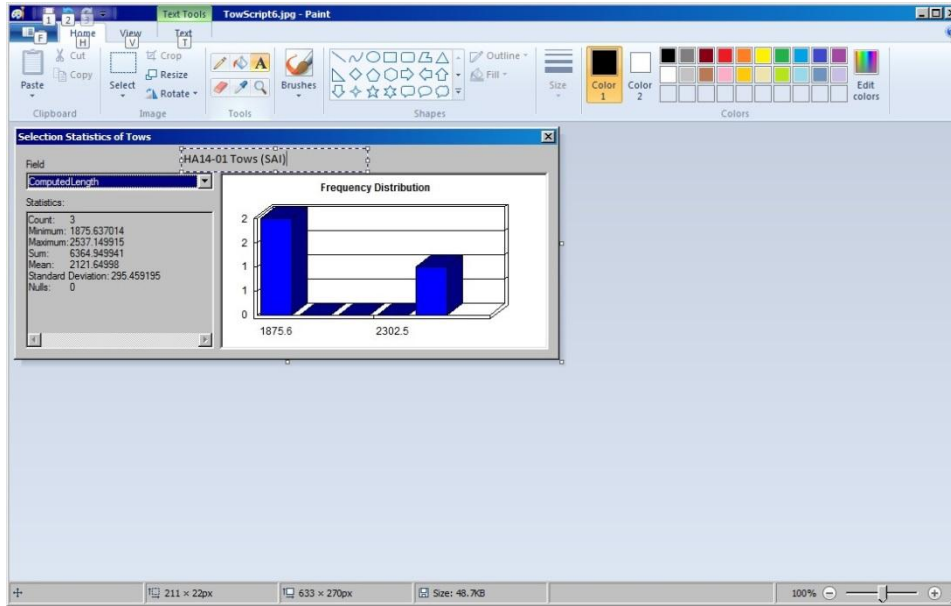
Figure 42. Statistics report print screen.

Further QA/QC

Check # of Segments are correct.

- Close the Tow Attribute table if it is still open
- Right-click Segments layer and select "Open Attribute Table"
- Look at **SegmentID** column to identify today's segments. Note the **SegmentID** are coded as YYYYMMDDTSS, where:
    - YYYY = Year
    - MM = Month
    - DD = Day
    - T = Tow Number
    - SS = Segment Number
    - So the below graphic has highlighted Segments 1-10 for Tows 1-3 for the date 4-13-2015
- All tows for the day should have 10 segments – confirm with the Tow Team Lead if any of the tows have less than 10 segments.

Figure 43. ARCGIS tow attributes table.

- If GPS was not consistently collecting the data, make a note in the field log the SegmentID without GPS.
- If the number of segments is more than the observation records, ensure the metadata text to see correct Start and End times were entered.
- Check Computed Length of each segment is not shorter than 100 or longer than 400.
- If it is shorter than 100, consult with Tow Team Lead to ensure the GPS was consistently collecting the data or the survey was not ended early.
- If GPS was not consistently collecting data, make a note in the field log SegmentID without GPS.
- If the survey was ended early, make a note of it in the field log.
- If it is longer than 400, check the metadata text to see if the Start and End time are entered correctly.

Notes:

- This script and processing regime is still in development.
- There may be errors and situations in which the script fails.
- Please keep a record of all instances so that corrections can be made to the script.
- If there is a situation in which the script does not work, download and save the GPS and Seabird SBE39 data and record the dive metadata which will allow processing of the tracks in Honolulu.

The tracks have now been processed.

Data from new days will be appended to the feature classes already in the Geodatabase.

Appendix G: Operating Garmin GPSMAP 78/78s and 76/76C in the Field

The Garmin GPSMAP 78 and 78s units are the primary GPS units used for tow operations. The Garmin GPSMAP 76/76C units can be used as back-up. Both Garmin GPS models operate similarly and can be used with the towboard script. Operational Garmin GPSMAP 78/78s and 76/76C GPS basics are as follows:

Garmin GPSMAP 78 and 78s: The menus of the GPSMAP 78 series can and should be customized prior to use in the field. Operational Garmin GPSMAP 78 and 78s basics are as follows:

Red light bulb Button—This is the on button. Hold until GPS turns on. When GPS is on it can be used to change the brightness of the screen by tapping it.

Menu Button—Double clicking on the *Menu button* navigates to the Main Menu. Displayed here are the power source and the remaining memory space on the GPS. This screen also displays the time, date, signal strength and battery power. Important components on the menu are:

> *Setup*—Ensure the following are initiated:

> - General: WAAS disabled
> - Time: (24 hour, Time Zone: Western Europe, Daylight Savings OFF)
> - Position Format: hddd.ddddd, Map Datum (WGS 84)
> - System:
>   - GPS:Normal
>   - Battery Type: Rechargeable
>   - Interface: Garmin Serial

> *Points* (Find ✐ Waypoints)

> - Once entered, pressing menu gives the option to delete the waypoints.
> - Click on a waypoint to modify it, delete it or to "Go to" for navigation purposes.

> *Tracks* (**Page (to the setup menu)** ✐ **Tracks**) —Depressing Enter on 'Tracks' produces the following options:

> - *Track Log:* Gives the option to record or not record the currently set up track. This should be the primary way to start and end a track.
> - Record Method: Time
> - Recording Interval: 00:05
> - Auto Archive: When Full

> **Track Manager (Depress 'Page' until 'Current Track' and 'Archived Track' is displayed**—Current track will recommend saving and naming options for the current track. Previously saved tracks can be viewed and edited on this page.

Quit Button—This leaves the current screen and returns to the previous one.

Page Button—Scrolls forward through the "Pages" on the GPS. The pages are: Map, Trip Computer, Setup, Compass Page and Track Manager. These pages can be customized by going to Setup > Page Sequence.

Navigation Button—Use this button to "Goto" a Point or Navigate a route. The compass page and map page directs to the current point.

A more detailed Garmin 76Map manual can be found on the NOAA PIFSC ESD T:\ drive at: T:\Towboard\Manuals & Instructions\GPSMAP78_OwnersManual.pdf

Garmin GPSMAP 76 and 76C:

Red light bulb Button—This is the on button. It will take you automatically to the Satellite Page. When enough satellites have been acquired (minimum of 3), the GPS will automatically go to the next screen page.

Menu Button—Double click on *Menu button* navigates to the Main Menu. Displayed here are the power source and the remaining memory space on the GPS. Important components on the menu are:

> *Setup*: ensure the following are initiated:
>
> - General: WAAS disabled
> - Time: (24 hour, +00:00UTC)
> - Location: Map Datum (WGS 84)
> - Interface: Set to Garmin
>
> *Points* (Menu❼Menu❼Points❼Waypoints)
>
> - Once entered, press menu to display the option to delete the waypoints.
> - Click on a waypoint to modify it, delete it or to "Go to" for navigation purposes.
>
> ***Tracks (Menu ❼Menu ❼Tracks ❼Menu ❼Setup Track Log)*** —Once entered press menu again and press "Setup Track Log". Ensure that the Interval is at 5 seconds and Record Method is on Time. To begin a tow track, scroll to Recording and press enter. Scroll to "Stop When Full". When ending a tow track ensure Recording is on Off.

Quit Button—This leaves the current screen and returns to the previous one.

Page Button—Scrolls forward through the "Pages" on the GPS. The pages are: Map, Compass, Highway, and Active Route/Goto Page.

Navigation Button—Use this button to "Goto" a Point or Navigate a route. The compass page, highway page, and map page directs the current point.

A more detailed Garmin 76Map manual can be found on the NOAA PIFSC ESD T:\ drive at: T:\Library\Manuals\GPSMAP76_OwnersManual.pdf

Appendix H: Telegraph and Additional Communications

Towed divers communicate with the vessel using a telegraph signal. This consists of an electrical connection that is completed when the diver pushes a plunger attached to a magnet to complete a circuit. The telegraph is clipped on to the fish diver's towboard, and commands can be sent from the diver to the surface support using a combination of short and long audible signals (Fig. 44). For more detailed information on the construction of the signal telegraph, see Appendix I.

Commands:

Stop: long

Start survey/End survey: short-short-long

OK/Resume (after stop): short-long-short

Go Left: short-short-short-short

Go Right: short-short-short

Speed up: short-short

Slow down: short

Emergency/Retrieve divers: more than 5 short

Take waypoint: long-short-short-long
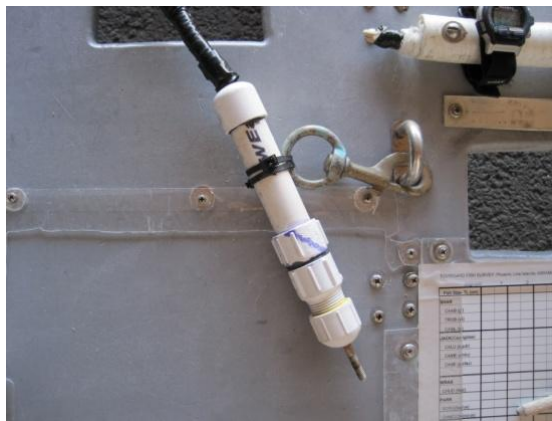
Figure 44. A signal telegraph clipped to the fish towboard.

Signals from the small boat to the divers

Single-engine rev: Towed-divers are required to send a signal to the small boat every five minutes, be it through an "o.k." signal or "start/end survey signal". If a period of time > 5 minutes elapses with no signal received, the small boat will use a single-rev from the engine to alert divers to send an "o.k. signal". Note that this may need to be repeated, with a 4–5 second pause between revs.

Double-engine rev (or diver recall bell/ding): This signal indicates divers should end their survey, but ascend to their normal safety stop (e.g. in areas where wave action is increasing along the shore line, shorter surveys due to end-of-day recovery logistics at the NOAA ships, etc.)

Multiple Repeating-engine rev (or diver recall yelp/siren): This signal indicates an emergency. Divers should end all survey activities and ascend immediately, foregoing their safety stops.

Appendix I: Telegraph Signaler Construction

The fish towed-diver tow line consists of a cable (Marine Grade 3/C 14AWG Bilge Pump Cable) covered in a braided nylon sheathing attached to a floating polypropylene line via plastic cable ties secured with electrical tape. Newer lines are constructed from a cable (Anchor Marine Grade 18/2 Duplex wire) coupled with a floating polypropylene line and all threaded through sections of braided nylon sheathing. This second design is more desirable because it has a lighter cable making it neutrally buoyant instead of negatively buoyant. For both designs the ends of the polypropylene line are knotted and secured with electrical tape around a heavy duty stainless steel swivel fasteners for attachment to the vessel transom and the towboard bridle. The floating polypropylene line is the main support and takes the tension. The signal cable should never support any tension, unless in an emergency. If tension is put on the signal cable it will likely be compromised and should be tested in-water before use.

The receiving end of the signal line, aboard the vessel, should be at least 6 m in length after the connection point of the polypropylene line to the vessel. This will allow for any later adjustments and maneuverability of the vessel. The end of the cable runs through a Pelican™ case (or equivalent) housing cushioned with foam to secure the signal components in rough seas (Fig. 45). The cable is secured to the box with PVC/electrical tape.

Figure 45. Receiving end of the signal with the battery, speaker, and electrical connections in a pelican case housing.

The free wire end connections then run:

1) **Black**—(solder the proper battery connector to the wire) straight to the battery. Ensure battery is fully charged before use.

2) **Red**—attached to the sounding device. Use a small section of wire to connect to the battery from the sounding device and solder the proper battery connector to the wire. Attach connectors to the battery accordingly.

3) **Brown**—This is a grounding wire left capped and out of the way (not present when using the duplex wire).

*Use liquid electrical tape on all connections to reduce future corrosion.

The diver end of the cable is a ~15-cm PVC tube capped on both ends and filled 7/8 with electric compound (3M Scotchcast® 2131). The initial end cap should have a hole drilled just large enough for the cable to fit. The terminal end of the tube should be made so that the cap can screw on and off. This will allow for any future alterations.

1) The **Red** and **Black** wire ends are soldered to the magnetic switch positioned in the tube just below or at the surface of the compound.

2) The **Brown** ground wire is secured in the compound but not connected to anything.

A hole is drilled into the center of the cap the diameter of a bolt (threaded end) which is used as the plunger. This plunger is pressed to close the circuit to the magnetic switch causing the sounding device to beep. (aka diver signals). The plunger consists of the bolt > magnet > spring (all of appropriate length depending on how full your tube is; how long of a bolt and your positioning of the terminal cap). These are then heat-shrink tube wrapped together allowing for the plunger to spring back into the off position. Do not cover the terminal end of the magnet with the heat-shrink tube. This will not allow for a connection to the magnetic switch. Test the magnet on the switch before building to ensure it is set correctly.

Appendix J: Training Curriculum for Advanced Towed-diver

Purpose: to teach and to familiarize divers and coxswains with standard towed-diver operations, the complexity of environmental conditions/man-made hazards seen in the field, and emergency situations they may encounter.

Requirements for ESD Benthic and Fish Towed-divers:

- Employed by NOAA PIFSC
- Have successfully completed preliminary towed-diver training with the Unit Dive Safety officer (UDS)
- Have NOAA Diver Certification
- One year of marine debris diving or scientific activities with ESD
- Basic Coxswain Certification

Desirable Experience

- Advanced Coxswain certified
- NDC NOAA Diver training or Mooring STE
- NOAA Marine Debris STE
- Small vessel maintenance and troubleshooting class
- Small vessel experience
- Open ocean transiting on vessels
- NOAA RV (*Hi'ialakai/Sette*) workbooks, clearance to launch and recover from NOAA vessels
- Previous work experience in remote and isolated areas

Basic Skills and Familiarization:

Mandatory Safety Equipment and Protocol

- Visual emergency signaling devices (safety sausage) and an auditory emergency signaling device (Dive Alert/whistle)
- Familiarity with 19' (5.8 m) SAFE™ vessel emergency equipment (KED Board, O2, neck collar, medical kits, fire extinguisher, EPIRB, etc.)
- Familiarity with dive tables (NOAA air, nitrox 32, nitrox 36 tables)

Personal Dive Gear and General Information

- Know limitations and advantages to various equipment and dive computers
- Gear consolidation/streamline: include only the necessities (keep the vessel deck clear; reduce weight for gear transfers during launch/recovery, reduce possibility of snagging, etc.). Personal dive bag utilized for regulator, mask, fins, gloves, extra wetsuit hoodie or other neoprene, and other loose equipment transfer. Weight belts should always be separate from all other gear.
- BC and scuba cylinder assembled prior to vessel launch, to be stored in the forward section of the 19' (5.8 m) SAFEBoat™. Regulator to be attached/removed post launch and recovery from/to NOAA vessel. For shore- based operations, BCs, regulators, and bottles may be pre-assembled prior to leaving the harbor for operations.

- All personal SCUBA gear should be stored in one place and separate from other vessel's gear (e.g. on the Hi'ialakai the tow team groups their dive gear between the pillars on the starboard side, forward of the cutout). This limits confusion and prevents gear mix-ups when loading and unloading small vessels.

Classroom (Off water) Training component (2-3 hours): Basic review of core skill sets

General Operations

- Deployment/recovery of towboards
- Vessel/tow line positioning relative to divers
- Engine operations/basic maneuvering protocol
- Use of bathymetry/fathometer and pre-planned tow survey points
- GPS tracking (waypoint/track line recording)
- Metadata recording: Navigation and Dive
- Assistance with working dives as stand-by divers
- Signal review: Diver to Tender vessel (ALL signals repeated twice after 2 second pause except Emergency!)
  - Short—Slow Down
  - Long (more than 3 seconds)—Stop
  - Short > Short—Speed Up
  - Short > Long > Short—OK
  - Short > Short > Long—Start/End Survey
  - Short > Short > Short—Go right
  - Short > Short > Short > Short—Go left
  - Long > Short > Short > Long—Take a position
  - **More than 4 Short**—Emergency: Recover divers immediately
- Diver Recall Review: Tender vessel to Diver (Repeated twice with a 2 second pause in between)
  - **Engine "rev"**—Give an OK/Checking in
  - **Two Engine "revs"**—end survey then begin ascent
  - **Three or more "revs"**—Emergency/Abort survey and ascend immediately

Identification/recognition of hazards

- Waves: reflection, ground, or wind-swell: May change vessel handling and position relative to divers. May increase turbidity/suspended bubbles at the surface, causing inaccurate fathometer readings.
- Currents: Surface, sub-surface, head/following, "down" currents or down-welling, eddies. May change vessel handling and position relative to divers;
  - Cardinal island "points" (e.g. north/south points off of Tinian, NW corner of Tutuila, South Point/Big Island, etc.)
  - Specific current, upwelling, tidal, or known eddy areas, e.g. west side eddies near the "Suicide cliffs"/Saipan, upwelling/eddies along the west side of Jarvis, Shark Fin Rock West Lanai down-current
  - Channels (e.g. Rose Atoll, down-current during outgoing tides)
- Bathymetric Features: Pinnacles, walls, ridges running perpendicular to shore

- o Often coupled with local oceanographic features (e.g. upwelling), or changes in waves, currents, and turbidity: May change vessel handling and position relative to divers
    - o Will often appear as a sudden decrease/increase in topside fathometer readings
    - o Divers may have to change positions/avoid obstacles, telegraph signals.
- Channels/Vessel Traffic: Specific to each region. Hawaii uses IALA-B (Red-Right-Return); CNMI, Guam, Samoa uses IALA-A (Green-Right-Return).
    - o Radio- each region uses specific VHF channel for harbor masters or harbor control. Certain operation limits at Pearl & Apra harbors.
- Weather: rain/squalls, sea spray, wind, lightning/electrical activity
    - o May change vessel handling and position relative to divers
    - o Coxswain visibility or auditory issues (e.g. ability to navigate into oncoming weather vs. following-weather; ability to hear the telegraph in wind or heavy rainfall)

Safety Reminders

Towed divers should:

- Thoroughly understand dive objectives and understand what risks accompany towed-diver operations.
- Review and refresh their skills at least once a year as well as prior to a deployment or field season.
- Decide if weather conditions/environmental risks and personal health status are worth the data collection. NOT dive if they feel there is inadequate protection from or preparation for environmental and man-made risks.

IN-WATER WORK

The goal is to familiarize towed-divers and coxswains with conditions affecting the small vessel and towed-divers. Towed-diver candidates and coxswains will encounter varying conditions (reflection, currents, surf, vessel traffic, and quickly changing bathymetry/walls, etc.). Vessels should be outfitted for standard field operations.

General Field Components (1–3 days)

- Operational briefings: loading vessels, launching and transiting to work site.
- Site/tow objectives
- Assessment of currents, weather/swell/tide conditions
- Review basic underwater tow techniques, use of the telegraph and diver recall
- Brief new tow team candidates on vessel limitations during normal operations
- Conduct vessel safety briefing related to surrounding hazards, brief for environmental conditions/rescues,
- Review basic medical stabilization procedures (e.g. O2 delivery, unconscious diver), and tow-team evacuation protocol/communications with the ship or to shore facilities
- Review Roles and Duties of Coxswain/Spotter
- Review gear preparations before deploying divers
    - o Communications
        - ▪ Telegraph signaling

- - Partner awareness/communication (hand signals, vocals)
    - Ship and radio communications/duties of coxswain and spotter
  - o Environmental conditions: topside
    - Assessment prior to diver deployment
    - Assessment during diver surveys and during recovery
- Conduct surveys in various conditions and scenarios.
- Return to pier; offload vessels and recap day's training. Brief participants with planning subsequent training days
- Clean, rinse and store vessel(s) and gear

Scenarios: Towed-diver Rescue: The goal is to reinforce rescue skills.

Spinal injury (1 per diver/coxswain)

Suspected DCS drills (1 per diver/coxswain)

Surf Zone Rescue: teach divers how to deal with a rescue and coordination with a small craft in the surf zone (1 per group)—ACT/Refresher: Surf training practical

Out of air Scenario (1 per diver pair): Goal is to teach divers proper methods for situation recognition, small boat telegraph signaling (i.e. slow and/or stop), and buddy breathing/sharing air while towboarding

Unconscious Diver (1 per diver pair/coxswain): Goal is to teach divers/coxswains how to safely rescue and recover an unconscious breathing/not-breathing diver.

Missing Diver Drill (1×/day): Goal is to familiarize divers with what to do within 1 minute, 5 minutes and 10 minutes of a diver going missing.

Loss of Communications (1×/day): Goal is to teach coxswains and divers to be aware of telegraph signals

Discussion of additional towed-diver scenarios: hooked bridle on tanks, line entanglements on the bottom, wildlife interactions.

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