PACIFIC ISLANDS FISHERIES SCIENCE CENTER

Coral Reef Ecosystem Division Standard Operating Procedures: Data Collection for Rapid Ecological Assessment Fish Surveys

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December 2011

Administrative Report H-11-08

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INTRODUCTION

This document is intended as a reference and provides guidelines for training, sampling, and data entry for the monitoring of reef fish populations as part of the Pacific Reef Assessment and Monitoring Program (Pacific RAMP) led by the Coral Reef Ecosystem Division (CRED) of the NOAA Pacific Islands Fisheries Science Center. The standard operating procedures outlined in this report apply to the Pacific RAMP surveys that CRED and its partners conduct in the coral reef ecosystems of ~ 50 primary islands, atolls, and shallow banks in the Hawaiian Archipelago (including the Papahānaumokuākea Marine National Monument), the Mariana Archipelago (Guam and the Commonwealth of the Northern Mariana Islands, including the Marianas Trench Marine National Monument), American Samoa, and the Pacific Remote Islands Marine National Monument (Wake, Johnston, Palmyra, and Kingman Atolls and Howland, Baker, and Jarvis Islands). As part of CRED's ecosystem assessment and long-term monitoring efforts, reef fishes and the benthic habitat are surveyed at Rapid Ecological Assessment (REA) sites selected using a stratified random sampling design. The details of the methods employed are outlined here.

EQUIPMENT

Each buddy team of two divers is equipped with a global positioning system (GPS) unit, along with a map of REA sites and a Dive and Navigation Information sheet, which remains on board the small boat while dives are conducted. For each dive, each buddy team has a 30-m transect reel (marked at 7.5, 15 and 22.5 m) and surface buoy (PAM float) attached to a 50-m dive reel. Transect lines are flagged at 7.5, 15, and 22.5 m to facilitate visual estimation of divers' survey areas that are adjacent cylinders 15 m in diameter and centered on the 7.5-m and 22.5-m points.

Each diver is equipped with a fish and habitat data sheet and underwater slate with pencil(s), a dive watch, and a *monopod*, which is a PVC stick consisting of a collapsible 1-m shaft marked at 10-cm intervals (Fig. 1). At least one, and preferably both, diver(s) in each buddy team carry an underwater digital camera that can be attached to the monopod for taking benthic photos. This camera also can be used to photograph any unknown fish species to be identified later. Each diver also should have an audio signaling device capable of getting a partner's attention. On deeper dives, or at a diver's discretion, a reserve air supply system is carried.

Figure 1.--The reference tool, called a monopod, used for taking benthic photos, measuring habitat vertical relief, and estimating the outer edge of a sample cylinder.

SITE SELECTION AND ASSESSMENT

The location of each REA site is determined using a stratified random sampling design. The benefit of this sampling regime is that sites are pseudo-randomly allocated to be representative of the general survey location (i.e., at the island or atoll level), while being distributed across depth zones and habitat types, two factors known to influence the composition of the fish assemblage. This approach allows for depth and habitat zone effects to be included in the analysis of the monitoring data collected. The target hard-bottom reef habitat (at depths of 1–30 m) is stratified using three depth zones of shallow (1–6 m), moderate (6–18 m), and deep (18–30 m) and three habitat zones of forereef, backreef, and lagoon.

The stratified random sampling locations are determined prior to each cruise using geographic information system (GIS) data on the bottom substrate type (hard/soft). These substrate and habitat maps have been generated from a combination of benthic habitat data from the NOAA National Centers for Coastal Ocean Science, habitat zones (e.g., forereef,) digitized from IKONOS satellite imagery or nautical charts, bathymetric data from the Pacific Islands Benthic Habitat Mapping Center, University of Hawai`i at Mānoa, and prior knowledge gained from previous visits to survey locations. Survey sites are randomly selected for each stratum, with 100 m set as the minimum distance between REA sites, using the Create Random Points tool in ArcGIS desktop software (ESRI, Redlands, Calif.).

Primary and alternate survey locations (REA sites) are selected prior to the start of each mission. Alternate sites serve as backup sites in the event that primary sites turn out to be unsuitable (e.g., because of mapping errors in depth or substrate type) or inaccessible. Before arrival at an island or atoll, the waypoints for REA sites at that island or atoll are uploaded into the fish team GPS units. Waypoints are named with a site ID (a standard three-letter island code and a three-number site code), along with the letter *A* to designate a primary site or a *B* to designate an alternate site (e.g., TUT-112A for a primary site at Tutuila Island in American Samoa).

Upon arrival at a REA site, divers visually inspect the site from the surface or by snorkeling, to confirm whether the site is indeed reef habitat in the expected depth range. If confirmation is not possible, divers attempt to drop directly from the waypoint and descend to the predetermined depth. Because our mission is to survey coral reef fishes, the area to be surveyed must contain a minimum of 75% hard-bottom (reef) habitat, which may necessitate some searching by a dive team. If a suitable site cannot be reached within 2 min, the dive should be aborted, and the team should travel to the next site or to an alternate site.

COLLECTING FISH DATA

The survey method used by CRED to record fish species, size, and abundance is a stationary point count (SPC) in which fishes of all size classes are recorded in a visually estimated cylinder, with a radius of 7.5 m, in a series of point-count *snapshots*. To avoid being overwhelmed by fish diversity and numbers, divers record fishes underwater using a set of simple rules that are similar to those outlined by Bohnsack and Bannerot (1986) and explained in this report. Prior to each dive, divers should enter the date, their name, name of buddy, and dive site ID on a Fish and Habitat data sheet (Fig. 2).

Date	Diver	Buddy	Site	Current: None Mod High

Rep A Vis: _____ m	Start: ___ : ___ End: ___ : ___	Rep B Vis: _____m	Start: ___ : ___ End: ___ : ___
Transect depth: _______m	Slope: Min depth: _____m Max depth: _____m	Transect depth: _______m	Slope: Min depth: _____m Max depth: _____m
Mobile Predators		**Mobile Predators**	
Parrots		**Parrots**	
Surgeons		**Surgeons**	
Wrasses		**Wrasses**	
Groupers/Anthias		**Groupers/Anthias**	
Goats		**Goats**	
Triggers		**Triggers**	
Angels		**Angels**	
Butterflies		**Butterflies**	
Damsels		**Damsels**	
Others		**Others**	

Habitat type √	**Complexity**	**Benthic Cover**	**Habitat type** √	**Complexity**	**Benthic Cover**
(General area)	(In cylinder)	Hrd Coral_____%	(General area)	(In cylinder)	Hrd Coral_____%
Boulders/Rock	Lo (< .25m) ____%	MA: _____%	Boulders/Rock	Lo (< .25m) ____%	MA: ______%
Reef (contin.)	M-Lo (.25-.75) ___%	CCA: ______%	Reef (contin.)	M-Lo (.25-.75) ____%	CCA: ______%
Reef (patch)	Med (.75-1.5) ____%	TA: ______%	Reef (patch)	Med (.75-1.5) ____%	TA: ______%
Pavement	M-Hi (1.5-3m)____%	Sand: ______%	Pavement	M-Hi (1.5-3m) ____%	Sand: ______%
Rubble	Hi (3-5m) ____%	_____Other (1)___%	Rubble	Hi (3-5m) ____%	_____Other (1)___%
Spur/groove	V-Hi (>5m) ____%	_____Other (1)___%	Spur/groove	V-Hi (>5m) ____%	_____Other (2)___%

Figure 2.--Sample Fish and Habitat data sheet used underwater to record data during SPC surveys.

Transect Layout

If the REA site is suitable, after settling on the bottom, a buddy team reels out a 30-m transect line along the depth contour. Divers should monitor their depth gauges to maintain a relatively constant depth. If two teams dive at the same survey site, the first buddy team should lay out one transect while the other team lays out a second transect, making sure that their cylinders are separated by at least 5 m. Site depth is recorded by each diver at the midpoint of the diver's cylinder, directly on the substrate.

Initial Species Identification (First 5 min)

After a transect line has been placed, the two divers of a buddy team move to the 7.5-m and 22.5-m marks, which serve as the center of their respective SPC cylinders (Fig. 3). Once in position, divers give each other the *OK* diver's hand signal to begin a survey and record the start time on their data sheet. During the first 5 min of the survey, divers create a list of all the fish species observed in their cylinder.

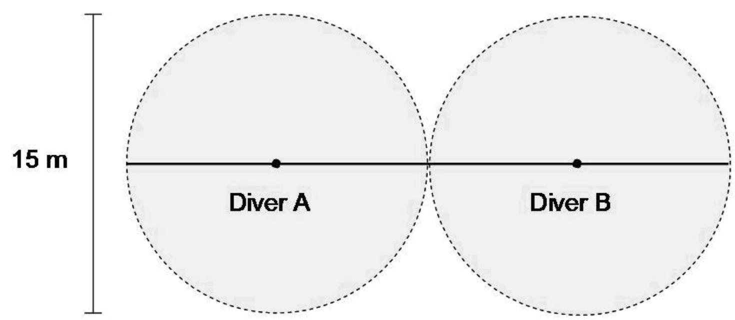


Figure 3.--Overhead view of the standard transect layout, with footprint of visually estimated cylinders, used for SPC surveys.

Counts and size estimates are not made during the initial 5-min period, unless the diver sees a rare, highly mobile species that is not likely to be seen again during the survey. Such taxa include Carcharhinidae (sharks), Carangidae (jacks), Lethrinidae (emperors), Sphyraenidae (barracuda), *Bolbometopon muricatum* (bumphead parrotfish), *Cheilinus undulatus* (humphead wrasse), *Variola louti* (lyretail grouper), *Chanos chanos* (milkfish), and *Aprion virescens* (green jobfish). If fishes of any of these taxa are sighted during the first 5 min of the survey, they should be counted and sized the first time they are seen in the cylinder. Divers should circle counts recorded during the initial 5-min period (to denote them as non-instantaneous).

To minimize disturbance of the surveyed fishes, divers should do their best to stay above the center mark of their cylinder and not swim around. Instead, divers should aim to rotate around the center axis of the SPC cylinder. While divers should attempt to identify all species as well as they can, it should be noted that priority species for surveys are the relatively large and mobile species that are well detected using this method. Therefore, divers should not focus their attention downward searching for small and cryptic species so much that they risk missing the larger and more highly mobile species that may be swimming through their cylinder. However, towards the end of the initial, 5-min, species-listing period, if time permits, each diver may spend some time scanning the substrate for smaller and more cryptic species. The fish and habitat data sheets are organized such that priority species are at the top of the form and small and cryptic species are at the bottom, thus, facilitating this prioritization. Fishes should be identified to species when possible; however, to avoid identification errors, fishes that closely resemble other species or cannot be positively identified should be identified to genus. For example, the snappers *Macolor niger* and *M. macularis* are often difficult to differentiate and should be recorded as *Macolor* spp. if the diver is not certain of the identification.

Counting and Sizing Fishes

After the first 5 min, divers again signal *OK* and then systematically go through the species lists that they created during the initial period, counting and sizing individuals present in their cylinder. If still present, the rare, highly mobile species should be recounted and sized. The new counts and sizes should be recorded and not circled, and the previous, circled (non-instantaneous) entries for that species should be crossed out.

Fish size should be estimated to the nearest centimeter for total length. For bony fishes, this is defined as the length from the tip of the snout to the tip of the longer lobe of the caudal fin (Fig. 4). Terminal-phase parrotfishes should be distinguished from juvenile- or initial-phase parrotfishes by writing a *T* next to the size on the data sheet. For some species, terminal phases are indistinguishable from initial phases, so this notation will not be possible.

Total length for rays (Myliobatidae) is measured from pectoral fin tip to pectoral fin tip (Fig. 5). If it can reasonably be done, care should be taken to accurately represent the abundance of fish of different sizes, so to better reflect the size distributions of individual species. Specifically, giving just an average size for a large school of fish should be avoided.

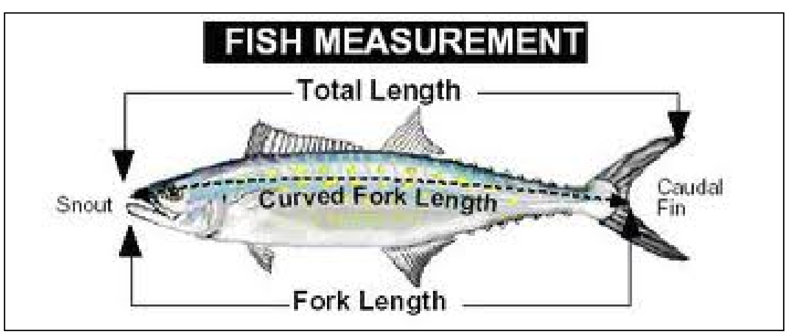


Figure 4.--Illustration of total length measurement for bony fishes.

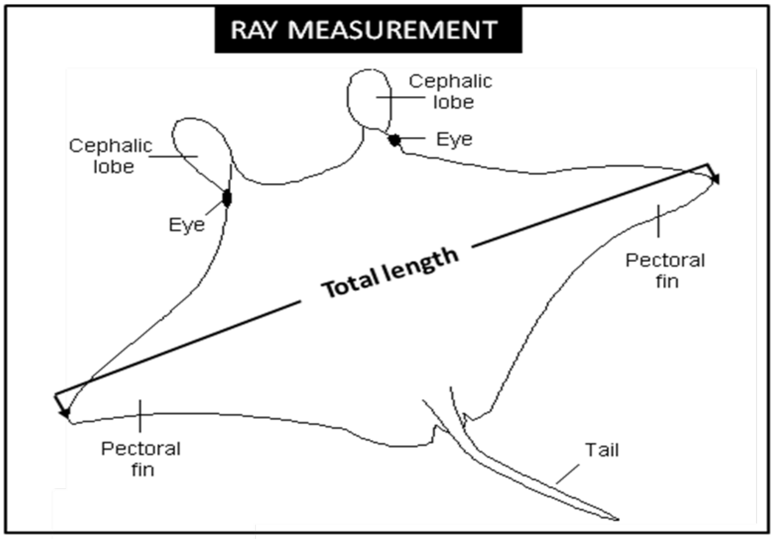


Figure 5.--Illustration of total length measurement for rays.

In addition to sizing fish, as a diver systematically works through a species list, the aim generally should be to make an instantaneous count of the entire cylinder for each taxon.

If no individuals from a species are present in the cylinder when the diver reaches that recorded species on the list, then the diver estimates the number of fish seen during the original sighting and circles the recorded count for that species; the circled values will later be entered into the database as non-instantaneous counts. If a large school is encountered during the initial 5 min period but is not present for the instantaneous count, then divers should estimate to the best of their ability the species, number of fish, and sizes of fishes that were present in that school.

For better efficiency, it may be possible to survey two or more species at a time, particularly if the densities of those species are low enough that divers are not overwhelmed. In general, if species are grouped for observation in this way, it makes sense to group species with similar behavior or appearance. Several species of small butterflyfishes, for example, might be counted and sized at the same time. Any species newly observed after the initial 5 min period are not to be recorded, except when a diver believes that the species was very likely present during the 5-min count but was missed (e.g., cryptic or relatively sedentary species that were almost certainly present but were overlooked during the initial 5 min).

Divers should treat each instantaneous count as if they are taking a snapshot of the density and sizes of all fishes of the taxa of interest observed in the survey cylinder at a single point in time. Therefore, if a large school of fish swims through the cylinder, the diver should, in their minds eye, attempt to freeze-frame that school as it swims through the survey area, counting only those fish in the cylinder at that moment and not continuing to count the rest of that school as it swims through the cylinder (Fig. 6). Divers should rotate at a rate such that they are able to count all fish present, but not double-count individuals. This rate may vary, depending on the taxon being counted.

Divers should remain as close to the center of their cylinders as possible while gathering count and size data and try to only rotate around the center point of their cylinders. However, when counting cryptic species (e.g., hawkfishes, damselfishes, and small wrasses), it will often be necessary for the diver to move several meters away from the center. For that reason, the survey of small benthic-associated or cryptic taxa should be left until the end of the count period of the SPC survey. It is difficult to accurately record cryptic species, such as hawkfishes and squirrelfishes, without swimming around the SPC cylinder. If the habitat is relatively homogenous in structure then an alternate approach can be taken to estimate the abundance of these cryptic species; divers can carefully count the cryptic species that are within view in a subsample of the cylinder and multiply that number to extrapolate to the area as a whole.

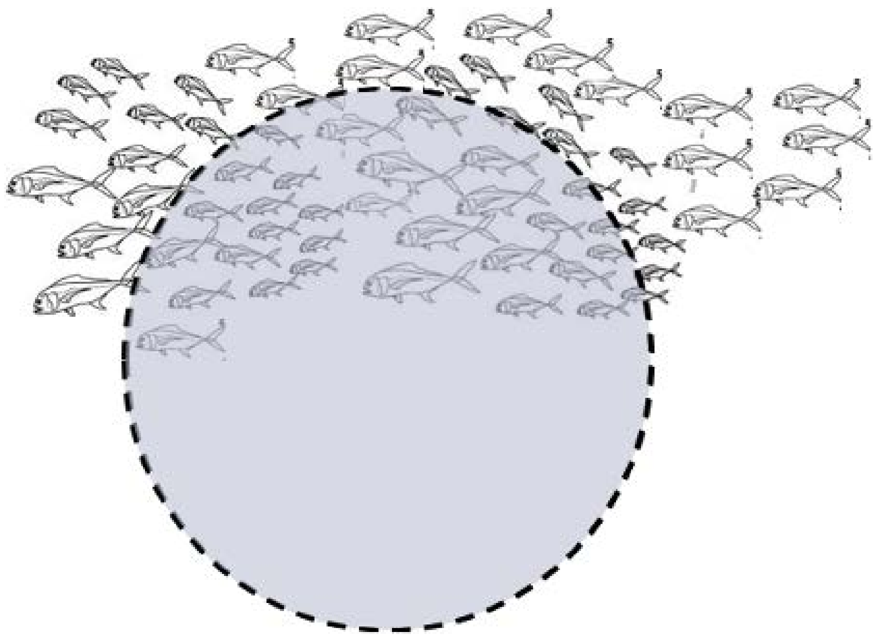


Figure 6.--A snapshot of a large school of fish as it swims through a cylinder. Only the fish in the shaded portion, which illustrates a visually estimated cylinder, should be counted.

Survey divers remain in visual contact at fixed locations along the transect line as they implement circular scans of their respective survey areas. For SPC surveys, divers may carry a reserve air supply system (RASS) if they choose. Alternatively, a RASS unit can be placed on the transect line at the 15-m mark between divers. Divers must carefully monitor their own and each others' air supply and communicate tank pressures, 10- and 20-mins into the dive, as well as at the 1000-psi mark. Divers must have an audio signaling device, which can be used in case of emergency or if they are otherwise unable to get their buddy's attention. Towards the end of the counting and sizing period, if divers feel they need to explore their respective cylinders more thoroughly (i.e., move off center), one diver moves towards the other diver to allow that diver to move freely without being more than 15 m away. Dives are carried out at a maximum depth of 30 m with a minimum visibility of 7.5 m. In case of low visibility (≤ 15 m), divers move closer to each other, overlapping their survey areas (Fig. 7). If this technique is used, it should be logged into the database as *Overlapped SPCs* in the Comments field. In cases where visibility is less than the standard 7.5-m SPC radius (i.e., when the edge points of an SPC cylinder cannot be properly discerned), the survey dive is aborted.

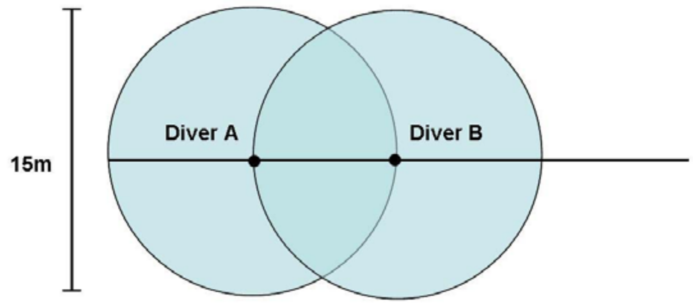


Figure 7.--Overhead view of a transect layout using overlapping SPC cylinders.

After each fish survey is completed, divers should record the end time on the data sheet (Fig. 2). The following sample-specific data also should be recorded:

Bottom Current: Estimated using three categories: None (negligible current), Mod (diver is able to stay in the same position with gentle to moderate kicking), High (diver struggles to stay in the same position).

Visibility: Horizontal visibility, in meters, estimated at depth by divers.

Transect Depth: Depth (m) taken at the midpoint of each of the divers' cylinders.

Slope: The minimum and maximum depths (in meters) within the same cylinder, referring to the minimum and maximum depths on the imaginary plane underlying the sample cylinder (for examples, see the section titled "Collecting Benthic Data," later in this report). Depths may be measured, or estimated in cases where measuring the downslope edge of the cylinder isn't safe (e.g., it is deeper than 30 m, or a diver may compromise remaining air supply by descending).

Divers also make visual estimates of benthic habitat variables within their respective cylindrical survey areas and record data as specified below in the "Collecting Benthic Data" section.

If permitted by bottom time and breathing gas supply, after the benthic photo transect, the 30-m transect may be moved to another location and the entire procedure is repeated. The transect line should be relocated at the same depth at least 5 m away from the boundary of the original SPC transect layout. CRED internal data analysis suggests that the completion of a greater number of sites with one replicate is superior to completing fewer sites with two replicates. Therefore, two replicates are completed only if there is sufficient time for two replicates but NOT sufficient time to transit to a new site and complete a replicate before returning to the ship.

DIVE AND NAVIGATION INFORMATION

The Dive and Navigation Information form (Fig. 8) is used to record the location of REA fish sites and time of surveys conducted each day. A new sheet should be filled out for each island. The following information is recorded on this form:

- **Island**: Island or atoll being surveyed (e.g., French Frigate Shoals or Tutuila Island)
- **Survey Team**: Fish REA
- **Local Time Zone (example)**: PST (Pacific Standard Time)
- **Local Time = UTC +/- (example)**: +10 hours
- **Vessel**: Current cruise vessel (e.g., Hi`ialakai)
- **Cruise ID**: The six-character code for the current cruise (e.g., HA-11-02)
- **Survey Year**: The current year (e.g., 2011)
- **Local Date**: The date at current location
- **Local time**: The time at current location
- **Site ID**: The seven-character code for current site (e.g., TUT-102A)
- **GPS Unit #**: Each dive team has a GPS with an assigned number (e.g., FISH 1).
- **Waypoint #**: The waypoint marked in the GPS corresponding to the dive site. Once the site is marked in the GPS, the name should be changed from the number automatically generated by the GPS unit (e.g., 014) to the Site ID name, omitting the letter *A* or *B*, (e.g., TUT-102).
- **Dive #**: Cumulative site number of the day (e.g., 1, 2, 3)
- **Latitude** and **Longitude:** Geographic coordinates for the position taken by the coxswain with the GPS directly over the dive site, once the divers have descended and set the surface buoy. This position should be taken directly from the GPS and should correspond to the waypoint number.
- **Zone Type**: Forereef, backreef, or lagoon. Can be abbreviated as F, B, or L.
- **Depth Strata**. Recorded as shallow, mod, or deep. Can be abbreviated as S, M, or D. Transect Depth is captured by each diver on the underwater data sheets (Fig. 2).
- **Divers**. Initials of the divers that participated in the survey.
- **Reps completed (A, B)**. Which replicates the divers completed (A, B, or A&B)
- **Benthic Photos**. Whether or not photos were taken (Y or N).
- **Other.** This space can be used to record short notes pertaining to the dive.
- **Notes**: This space can be used to record any additional information judged to be important by data collectors.

Island: ______________________

Survey Team: ______________________

Local Time Zone: ______________________

Local Time = UTC +/- ______ Hours

Dive and Navigation Information

Coral Reef Ecosystem Division

NOAA Pacific Islands Fisheries Science Center

Fish REA

Vessel: ______________________

Cruise ID: ______________________

Survey Year: ______________________

Local Date	Local Time	Site ID	GPS Unit #	Waypoint #	Dive #	Latitude (N/S 00.00000)	Longitude (E/W 00.00000)	Zone Type (forereef / backreef / lagoon)	Depth Strata (shallow/mid/deep)	Divers (initials)	Reps completed (A, B)	Benthic Photos	Other (add'l notes)

Additional Notes:

Date	Dive #	Site ID	Notes (abnormal current or visibility conditions, transect notes, new deployments, collections made, etc.)

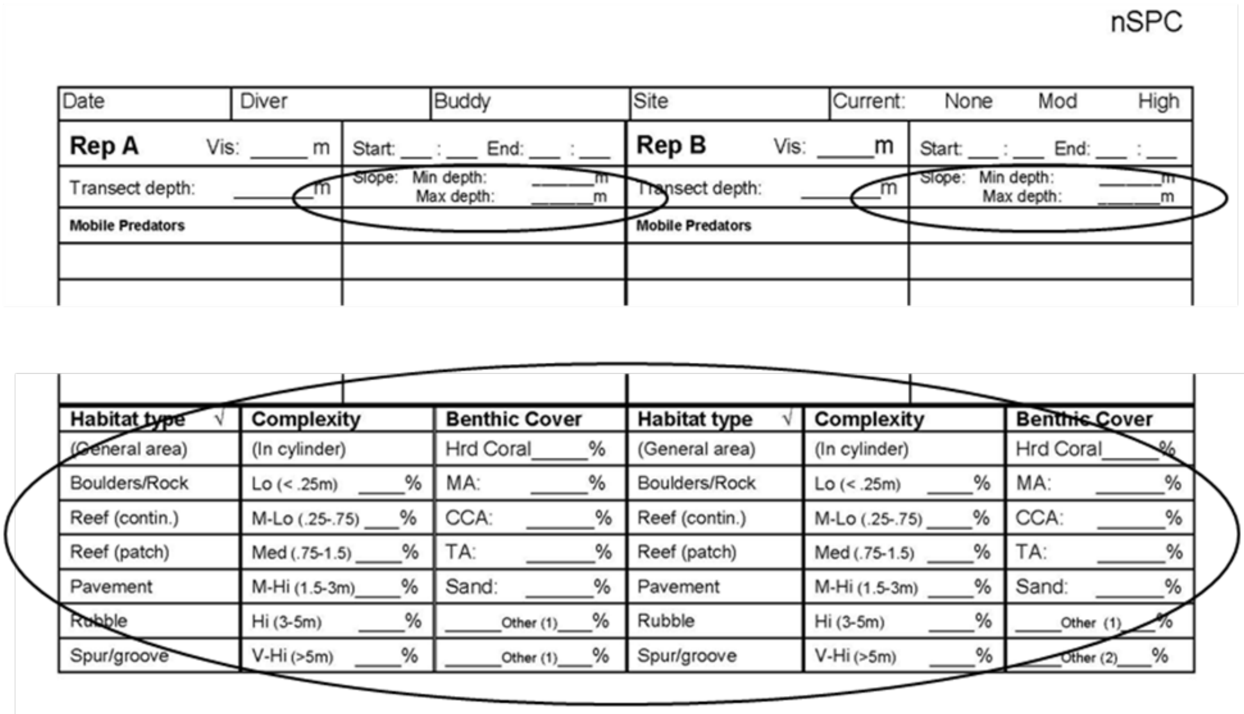
Figure 8.--Sample Dive and Navigation Information form used for diving activity at fish REA sites.

COLLECTING BENTHIC DATA

At the end of an SPC survey, both divers conduct visual benthic estimates within their respective cylinders, estimating slope, benthic cover, habitat type, and habitat complexity and recording them at the bottom of a Fish and Habitat data sheet (Fig. 9). Benthic photos are taken along the entire 30-m transect line, and site photos are taken of the survey area.

Slope

As outlined previously, slope is recorded as part of the sample-specific data collection. Divers record the minimum and maximum depths (in meters) within their cylinder, meaning the minimum and maximum depths on the imaginary plane underlying the survey cylinder (Figs. 9 and 10). As stated previously, if measurement of depths is not possible because of air supply or allowable dive time limits, depths may be estimated instead.



nSPC

Date	Diver	Buddy	Site	Current: None Mod High
Rep A Vis: ____ m	Start: ___ : ___ End: ___ : ___		Rep B Vis: ____ m	Start: ___ : ___ End: ___ : ___
Transect depth: ____ m	Slope: Min depth: ____ m Max depth: ____ m		Transect depth: ____ m	Slope: Min depth: ____ m Max depth: ____ m
Mobile Predators			Mobile Predators	

Habitat type √	Complexity	Benthic Cover	Habitat type √	Complexity	Benthic Cover
(General area)	(In cylinder)	Hrd Coral____%	(General area)	(In cylinder)	Hrd Coral____%
Boulders/Rock	Lo (< .25m) ____%	MA: ____%	Boulders/Rock	Lo (< .25m) ____%	MA: ____%
Reef (contin.)	M-Lo (.25-.75) ____%	CCA: ____%	Reef (contin.)	M-Lo (.25-.75) ____%	CCA: ____%
Reef (patch)	Med (.75-1.5) ____%	TA: ____%	Reef (patch)	Med (.75-1.5) ____%	TA: ____%
Pavement	M-Hi (1.5-3m) ____%	Sand: ____%	Pavement	M-Hi (1.5-3m) ____%	Sand: ____%
Rubble	Hi (3-5m) ____%	____ Other (1) ____%	Rubble	Hi (3-5m) ____%	____ Other (1) ____%
Spur/groove	V-Hi (>5m) ____%	____ Other (1) ____%	Spur/groove	V-Hi (>5m) ____%	____ Other (2) ____%

Figure 9.--Areas where benthic data are recorded on the Fish and Habitat data sheet.

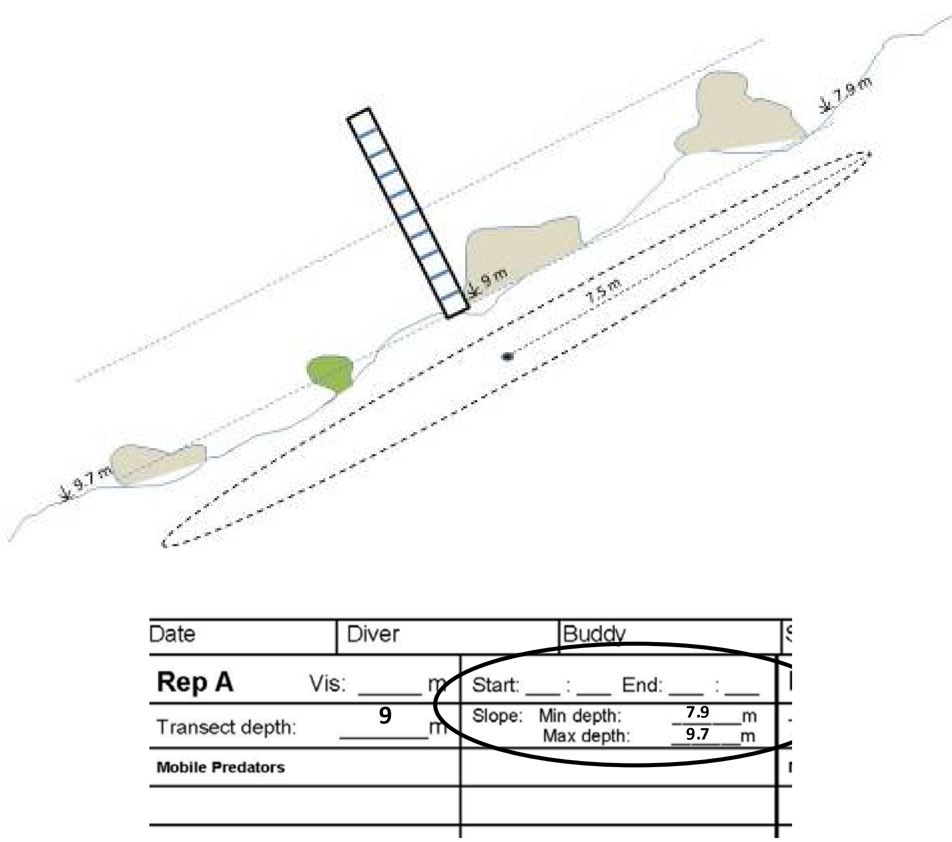
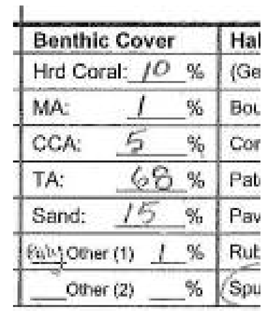


Figure 10.--Measuring slope for sample-specific data collection.

Benthic Cover



Benthic Cover	Hal
Hrd Coral: 10 %	(Ge
MA: 1 %	Bou
CCA: 5 %	Cor
TA: 68 %	Pat
Sand: 15 %	Pav
[illegible] Other (1) 1 %	Rub
___ Other (2) ___ %	(Spu

Percentage of non-motile benthic cover is estimated from an aerial (planar) view for six categories: hard corals, macroalgae, crustose coralline algae, turf algae, sand, and other. Percentages should total 100%. The six categories are defined as follows:

Hard Corals (Hrd Coral) are characterized by colonies or portions of colonies that are covered with living tissue. Living tissue usually appears colored (e.g., olive green, brown, bluish lavender) because of the presence of pigments in coral tissue or their symbiotic zooxanthellae.

Macroalgae (MA) are algae that are visible to the naked eye, with evident complex structure (i.e., distinct leaves and holdfasts). Canopy heights are typically > 10 mm. Examples are the genera *Halimeda, Microdictyon, Dictyota*, and *Liagora.*

Crustose Coralline Algae (CCA) are encrusting red algae that deposit calcium carbonate as part of their structure, often giving a pinkish or lavender appearance to the encrusted substrate. In some areas, these algae can also form 3-D spires.

Turf Algae (TA) comprise a category that encompasses a wide range of species and growth forms. Turf algal assemblages often include small forms, which if allowed to grow further, would develop into macroalgal plants. Nearly all apparently bare rock or limestone substrate on a reef, if checked closely enough, will have some form of algae growing on it. For that reason, turf is defined as a very broad category that is in practice similar to being not any other defined category. When estimating benthic cover, if one doesn't clearly see obvious corals, macroalgae, crustose coralline algae, organisms in the "Other" category, or sand, it is always recorded as cover of turf algae.

Sand is unconsolidated sediment, ranging in texture and size from fine to coarse and including both inorganic (eroded rock) and organic (eroded fragments of calcareous organisms) sediments. It is assigned to areas that can clearly be distinguished as granular, loose sand, usually deep enough to stick your finger in up to the first joint.

Other living cover includes soft corals (family: Alcyoniidae), mat tunicate (e.g., *Diplosoma* sp.), zoanthids (e.g., *Palythoa* spp.), corallimorphs (*Rhodactis howsei*), and giant clams (*Tridacna* spp.). It does not include mobile invertebrates, such as sea urchins.

Habitat Type

Habitat type	√	Co
(General area)		(Cy
Boulders/Rock		Lo
Contin reef	√	M-L
Patch reef		Me
Pavement		M-H
Rubble		Hi (
Spur/groove		V-H

Reef (or habitat) type is characterized by selecting the most appropriate of six choices: pavement, spur and groove, continuous reef, boulders/rock, rubble, or patch reef. Because of the great variety of reef habitats comprising ecosystems around the many Pacific islands surveyed by CRED, a survey area may not fall neatly into one of these categories. The category with the definition that most closely fits the habitat should be selected.

The categories for habitat type are modified from Brandt et al. (2009):

Pavement: Flat, low-relief, consolidated substrate, typically composed of calcareous or basaltic elements, which have become cemented together by biogenic and physical processes. Coverage may include macroalgae, hard coral, zoanthids, and other sessile invertebrates that may be dense enough to begin to obscure the underlying surface.

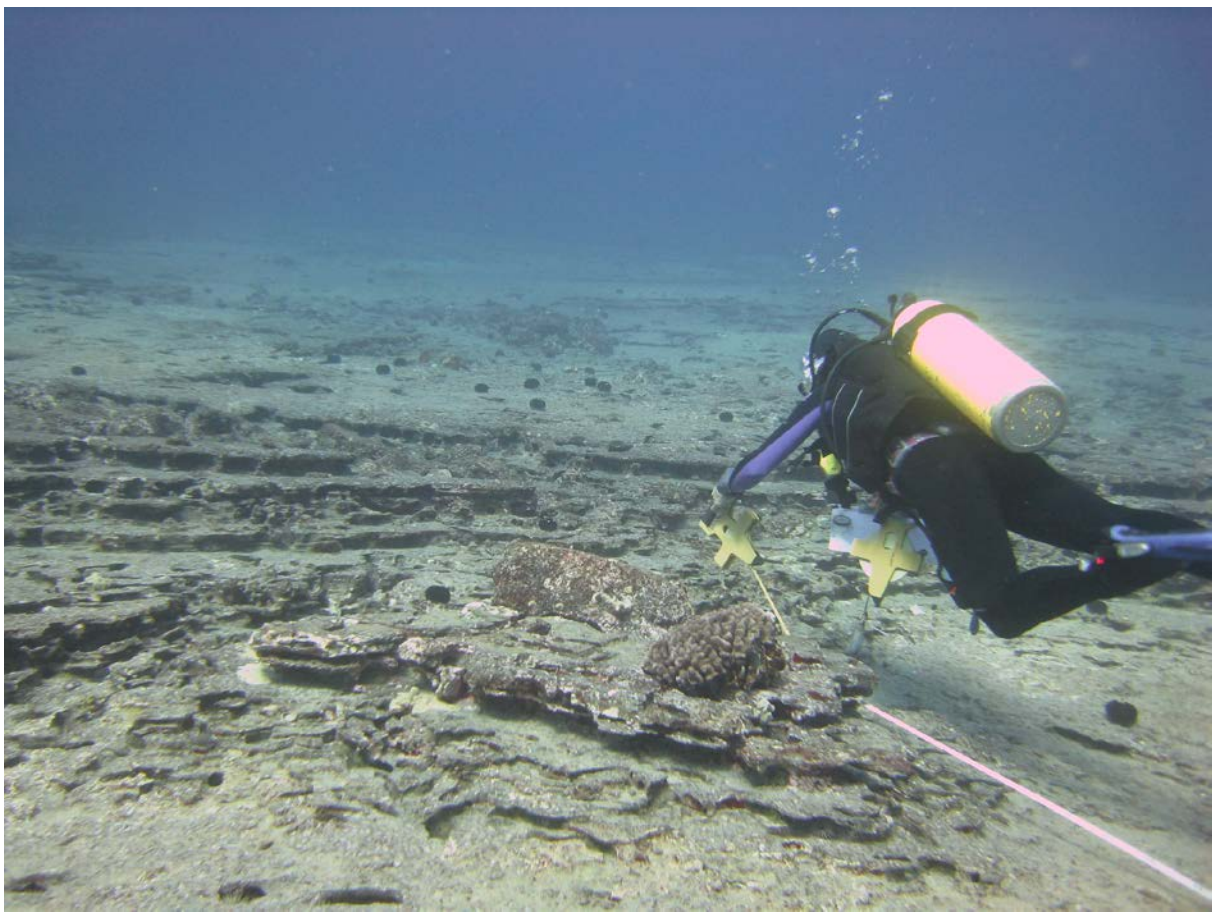


Figure 11.--Example of pavement habitat. *Photo by D. White, Hawai`i Department of Land and Natural Resources*

Spur and groove: Habitat with alternating sand and coral formations that are oriented roughly perpendicular to the shore, bank, or shelf (Fig. 12). The coral formations (spurs) of this habitat type typically have a high, vertical relief relative to pavement with sand channels and are separated from each other by 1–5 m of sand or hard-bottom (grooves) substrate, although the height and width of these elements may vary considerably.

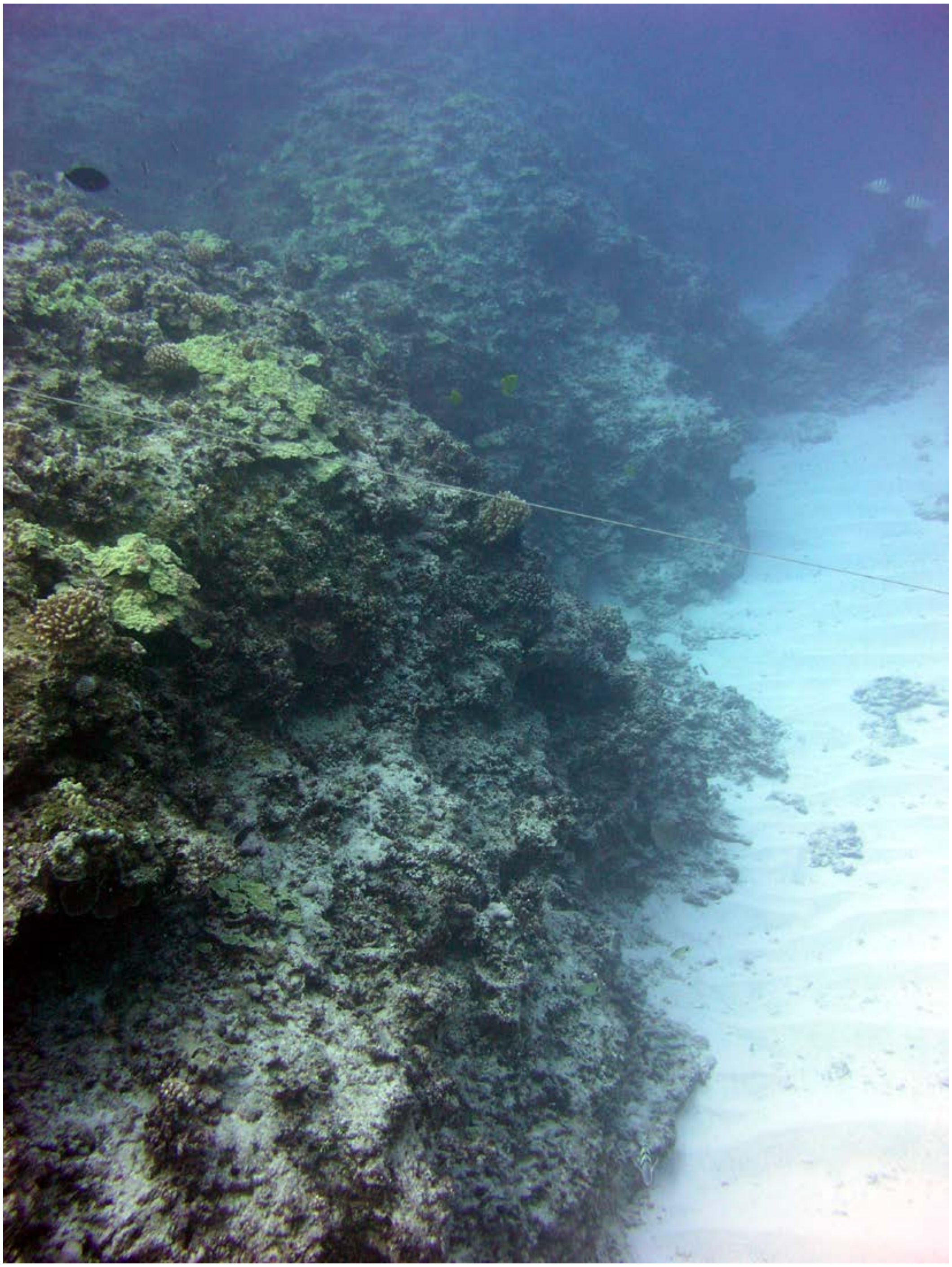


Figure 12.--Example of spur-and-groove habitat. Another spur runs parallel to this one, out of the frame to the right. *NOAA photo*

Continuous Reef: Hard-bottom substrate with corals, also referred to as aggregate or consolidated reef (Fig. 13). This habitat type may have high relief but lacks the repeating, parallel channels of sand or pavement of the spur-and-groove type. Most reefs that do not obviously fall in other types are recorded as continuous reef.

Figure 13.--Example of continuous reef. *NOAA photo*

Boulders/Rock: Solid carbonate blocks or boulders or volcanic rock with an average diameter > 10 cm, with very little benthic cover present (Fig. 14).

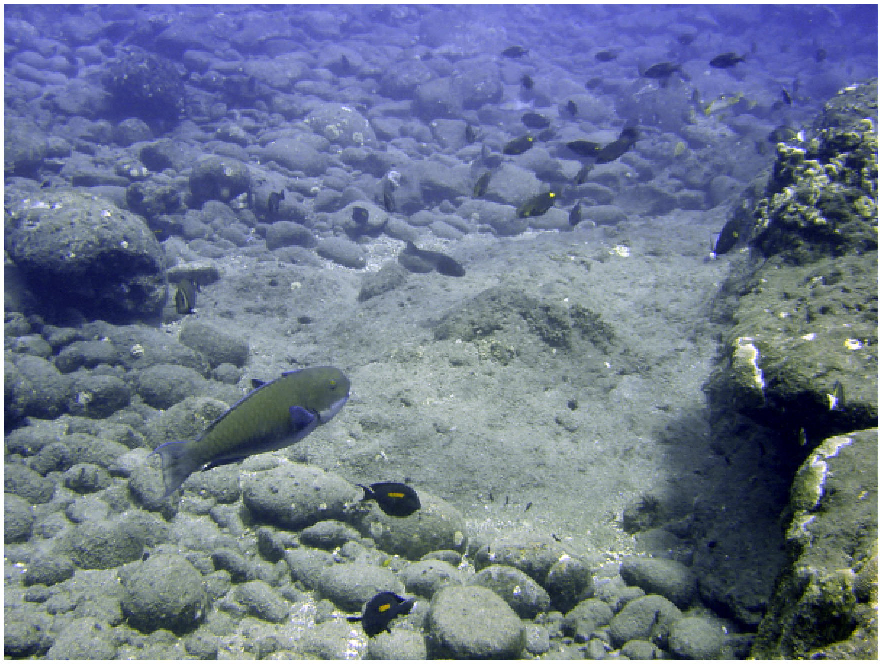


Figure 14.--Example of boulder habitat. *NOAA photo*

Rubble: Unconsolidated, small (< 10 cm) fragments of coral skeletons or reef rock often colonized with filamentous or other macroalgae (Fig. 15). This habitat often occurs landward of well-developed reef formations in reef crest or backreef zones.

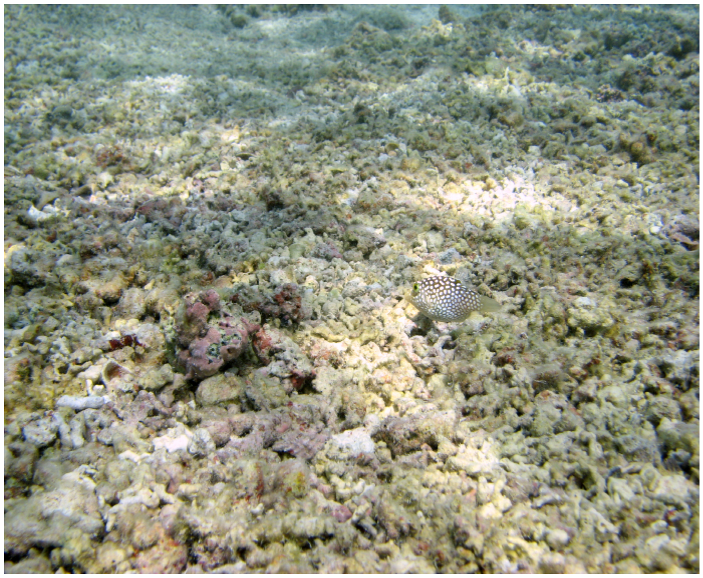


Figure 15.--Example of rubble habitat. *NOAA photo*

Patch Reef: An assemblage of coral colonies or consolidated carbonate formations that are isolated from other coral reef formations by sand or other habitats and that have no organized structural axis relative to the contours of the shore. This type is most commonly noted in lagoons (e.g., Rose Atoll) or backreefs (e.g., northern Pearl and Hermes Atoll and Midway Atoll). An aerial photo (Fig. 16) shows a number of patch reefs in southern Kāne`ohe Bay, O`ahu, Hawai`i.

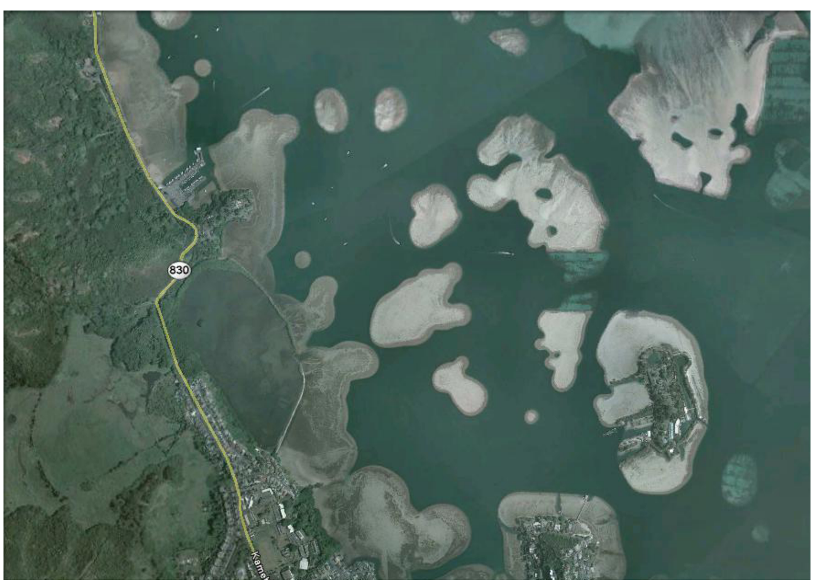


Figure 16.--Aerial view of patch reefs in southern Kāne`ohe Bay, O`ahu, Hawai`i. © 2011 Google and satellite imagery © 2011 DigitalGlobe, GeoEye, and U.S. Geological Survey.

Habitat Complexity

Habitat complexity is assessed by estimating the percentage of each category that best describes the scale of vertical relief within a survey cylinder: low (< 0.25 m), medium-low (0.25–0.75 m), medium (0.75–1.5 m), medium-high (1.5–3 m), high (3–5 m), and very high (> 5 m). The diver visually estimates how much of the cylinder is comprised by each level of complexity, and notes the percentages next to the appropriate categories. Care should be taken to ensure percentages total 100%. The 1-m monopod, which is marked in 10-cm increments, can be used as an aid in measuring complexity (Fig. 17).

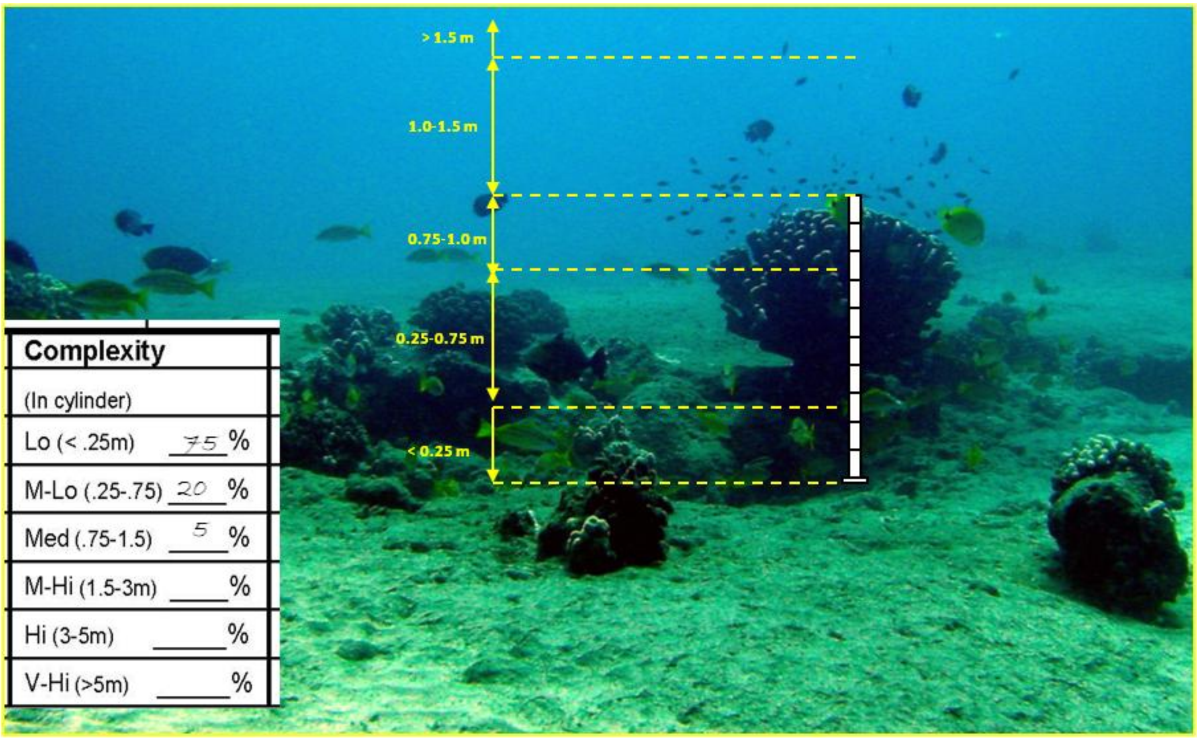
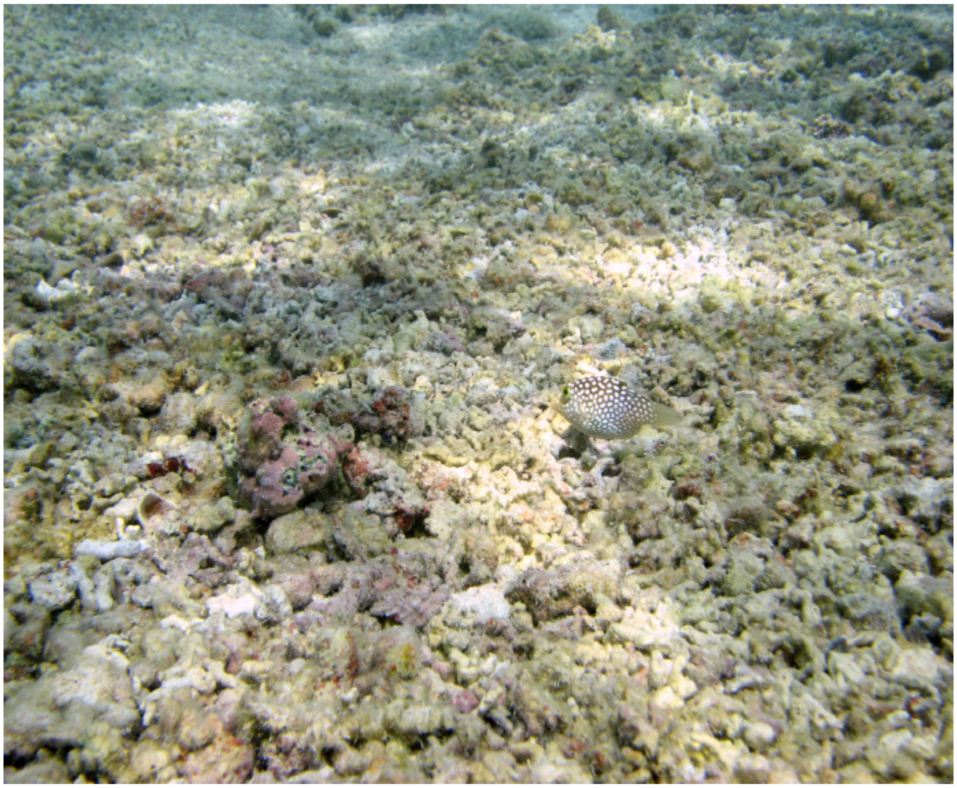
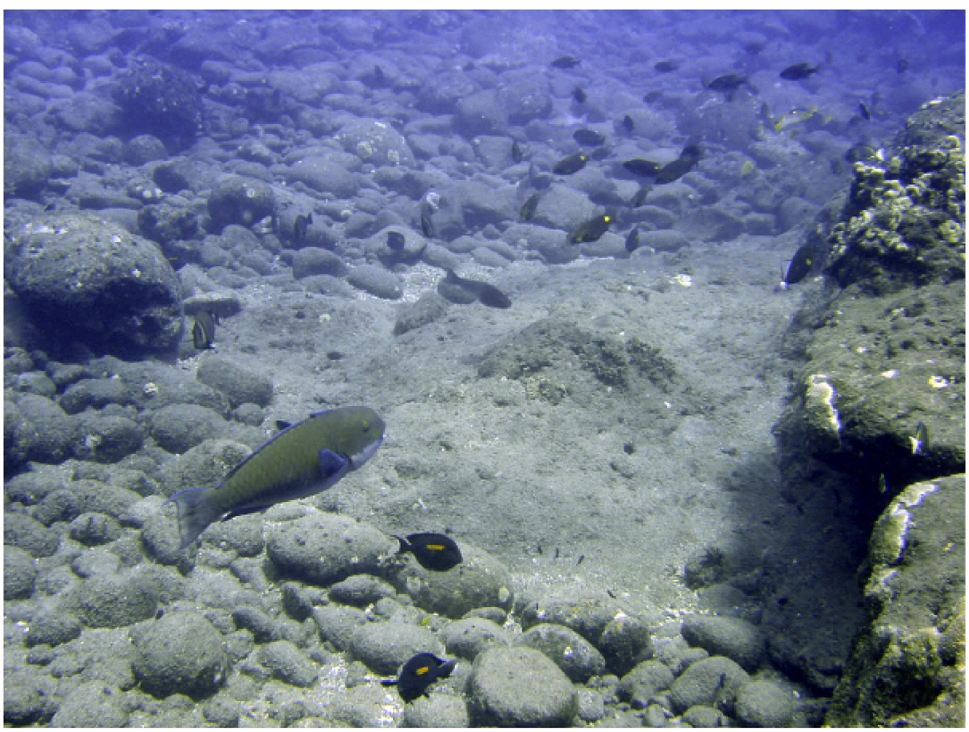


Figure 17.--Example of estimating vertical relief using vertical height categories. *NOAA photo*



Complexity	
(In cylinder)	
Lo (< .25m)	100 %
M-Lo (.25-.75)	%
Med (.75-1.5)	%
M-Hi (1.5-3m)	%
Hi (3-5m)	%
V-Hi (>5m)	%

Figure 17.--Example of habitat characterized as 100% low complexity. *NOAA photo*

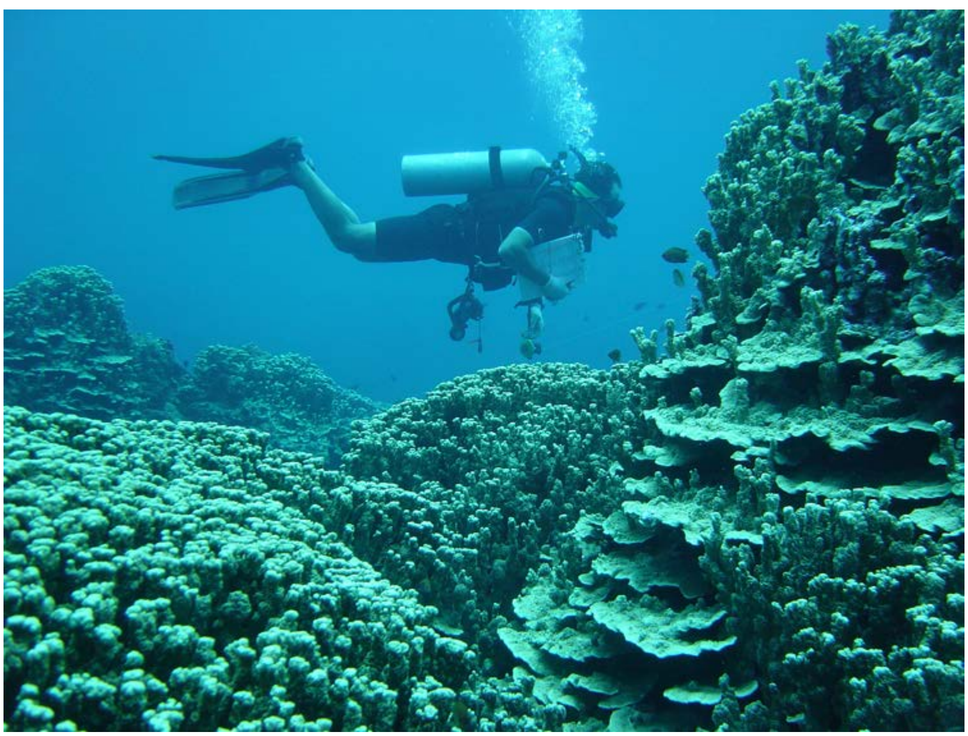


Complexity	
(In cylinder)	
Lo (< .25m)	50 %
M-Lo (.25-.75)	40 %
Med (.75-1.5)	10 %
M-Hi (1.5-3m)	%
Hi (3-5m)	%
V-Hi (>5m)	%

Figure 18.--Example of habitat characterized as medium-low complexity. *NOAA photo*

Complexity	
(In cylinder)	
Lo (< .25m)	10 %
M-Lo (.25-.75)	40 %
Med (.75-1.5)	50 %
M-Hi (1.5-3m)	%
Hi (3-5m)	%
V-Hi (>5m)	%

Figure 19.--Example of habitat characterized as primarily medium complexity. *NOAA photo*



Complexity	
(In cylinder)	
Lo (< .25m)	%
M-Lo (.25-.75)	%
Med (.75-1.5)	70 %
M-Hi (1.5-3m)	30 %
Hi (3-5m)	%
V-Hi (>5m)	%

Figure 20.--Example of habitat characterized as medium to medium-high complexity. *NOAA photo*

Complexity	
(In cylinder)	
Lo (< .25m)	____%
M-Lo (.25-.75)	____%
Med (.75-1.5)	____%
M-Hi (1.5-3m)	____%
Hi (3-5m)	70 %
V-Hi (>5m)	30 %

Figure 21.--Example of survey area with numerous pinnacles, categorized as habitat of high to very high complexity. *NOAA photo*

Benthic Photo Protocol

After visual assessments of the fish assemblage and benthic habitat are complete, the buddy pair takes digital still photographs of the benthos. The first photo taken at each REA site is a photo of the slate with the dive site ID. The diver should utilize their slate to white balance the camera at this time. Then, one diver takes site photos and photos of the substrate (benthic photos) along the transect line, while the other diver follows behind reeling up the transect line. For the site photos, two photos are taken to show the general habitat in each cylinder (Fig. 22). For the photo transect, photos of the benthic substrate are taken at one meter intervals along the right hand side of the 30-m transect line, spanning the length of the two SPC cylinders. The camera should be mounted on the monopod, to allow photos to be taken at a fixed height (1 m) above the seafloor. If two SPC replicate pairs are surveyed at one site, photos are taken at 2-m intervals on the transect line of each paired cylinder, to yield a total of 30 photos evenly spaced across the survey area.

Figure 22.--Examples of site photos taken along the transect line after SPC surveys. *NOAA photos*

The diver-photographer should look at the camera viewfinder during and after taking pictures to ensure that orientation of the monopod is correct (Fig. 23) and that the image is not blurry.

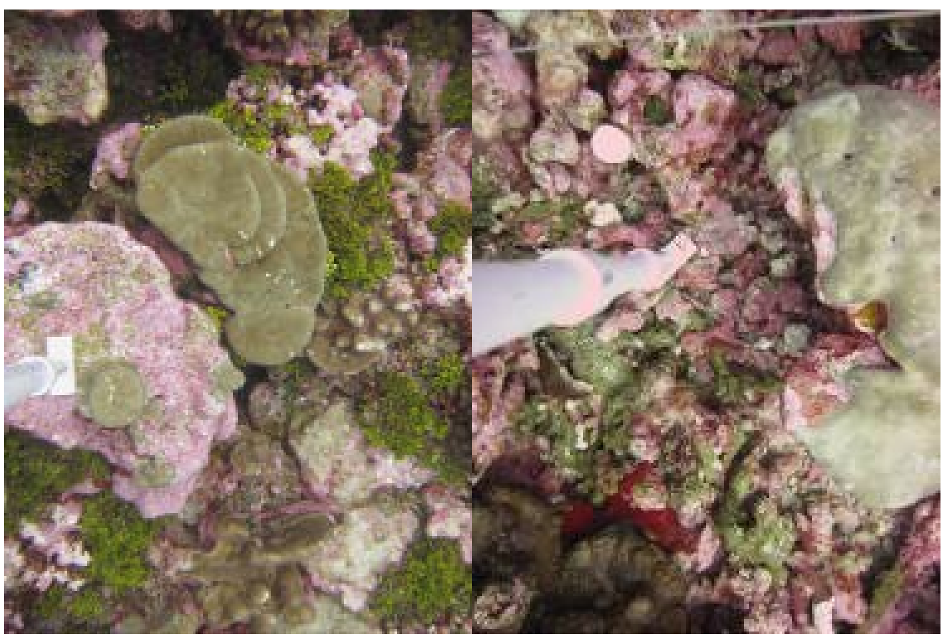


Figure 23.--Examples of (*a*) ideal and (*b*) incorrect stick placements. *NOAA photos*

If the monopod is crooked (Fig. 23[b]), an object is in the way, or the image is blurry, another photo should be taken.

ARCHIVING PHOTOS

After each day's field operations, benthic images are uploaded to the ship's data server and must be stored in the following manner. A directory is designated on the ship's drive for storing all benthic photos. Directory organization, for example, should follow the one also used on the main CRED server: V:\Cruise\CruiseData\HA1008 MHI\Optical\MOL\REA\FISH\MOL-160. In each REA site folder are two folders: *Photo_Quads* and *Site_Photos*. In each of these folders are subfolders for each replicate survey, *A* and *B*, where all benthic and site photos are uploaded. In addition, in an *OTHER* folder at the REA directory level, all photos that are not site photos or benthic photos (images taken along transects), such as pictures taken for purposes of fish identification, should be stored in a folder called firstinitial_lastname (e.g., V:\...HA1008 MHI\Optical\MOL\OTHER\J_SMITH). File names of images should not include spaces or special characters, including parentheses. Divers should consult the data manager on their cruise to ensure that they put things in the right place.

DATA ENTRY AND 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 into the fish Microsoft Access database that is stored on the ship's data server. The name of this database carries a prefix for the current cruise (e.g., HA1008 CRED Fish-TDS Database.mdb). Data entry should follow the methods outlined in the forthcoming report titled, *Coral Reef Ecosystem Division Standard Operating Procedures: Training Protocols for Conducting Rapid Ecological Assessment Fish Surveys*. Initial data entry and quality control is the responsibility of the diver who collected the data. Quality control should include error checking the entered data against the data sheet immediately after data entry as well as quality checking data with a partner once data for all sites surveyed that day have been entered. These initial quality control measures should be completed by the end of each respective leg of a cruise, but ideally by the end of each day. If errors are found, the database should be corrected to reflect the data on the data sheet.

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1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. U.S. Dep. Commer., NOAA Tech. Report NMFS 41, 15 p.

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2009. A cooperative multi-agency reef fish monitoring protocol for the Florida Keys coral reef ecosystem. Natural Resources Report NPS/SFCN/NRR – 2009/150. National Park Service, Fort Collins, Colorado.