PACIFIC ISLANDS FISHERIES SCIENCE CENTER

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

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December 2015

Administrative Report H-15-07

doi:10.7289/V5SN06ZT

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Administrative Reports may be cited as follows:

Ayotte, P., K. McCoy, A. Heenan, I. Williams, and J. Zamzow. 2015. Coral reef ecosystem program standard operating procedures: data collection for rapid ecological assessment fish surveys. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96818-5007. Pacific Islands Fish. Sci. Cent. Admin. Rep. H-15-07, 33 p. doi:10.7289/V5SN06ZT

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doi:10.7289/V5SN06ZT

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December 2015

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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 Program (CREP) of the NOAA Pacific Islands Fisheries Science Center (PIFSC). The standard operating procedures (SOP) outlined in this report apply to the Pacific RAMP surveys that CREP and its partners conduct in the coral reef ecosystems of ~ 40 primary islands, atolls, and shallow banks in the Hawaiian Archipelago (including 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 Island Areas Marine National Monument (Wake, Johnston, Palmyra, and Kingman Atolls and Howland, Baker, and Jarvis Islands). As part of CREP'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.

KEY UPDATES TO THE REA SOP

This document replaces the December 2011 Administrative Report H-11-08 **Coral Reef Ecosystem Division Standard Operating Procedures: Data Collection for Rapid Ecological assessment Fish Surveys.** Highlights of key updates are listed below:

- Addition of 5-10 min and 10-30 min tallying and enumeration of fishes (p. 7)
- Addition of tallying and enumeration of fishes for Presence data (p. 7)
- Benthic cover categories adjusted (p. 13)
- "Terminal" distinction for parrotfish only for the Hawaiian Islands (p. 12)
- Habitat Types expanded (p. 18)
- Complexity (Substrate Height) measurements adjusted (p. 25)
- Urchin density estimates included (p. 27)

EQUIPMENT

Survey dives are conducted from small (6-9 m) boats launched from the support ship to the pre-selected, random stratified dive sites. Each morning the following equipment should be packed and transported onto the small boat prior to launching.

On board the small boat
- Global Positioning system (GPS) unit loaded with pre-selected, random stratified sites
- REA site map
- Dive navigation sheet

Buddy pair:
- 30 m transect reel (with flagging tape marked at 7.5, 15. 22.5 m)
- Surface marker buoy with 50-m dive reel
- Secchi disk

Individual diver:
- Fish and habitat data sheet on underwater slate
- Pencils
- Dive watch with audible count down timer
- Meter stick (PVC stick consisting of a collapsible 1-m shaft marked at 10-cm intervals)
- Underwater digital camera for taking benthic photos and/or taking photographs of any unknown fish species to be identified later
- Audio signaling device capable of getting their partner's attention
- For dives deeper than 6-m – reserve air supply system (RASS)

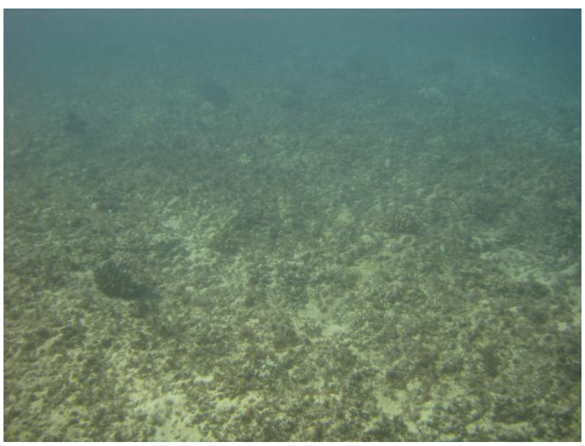
SITE SELECTION AND ASSESSMENT

The location of each REA site is determined using a random stratified design. The benefit of this sampling regime is that sites are allocated to be representative of the general survey location (i.e. at the island or atoll level), while being distributed across strata based on depth zones and habitat types, factors known to influence the composition of the fish assemblage. The survey domain (i.e. target habitat for surveys) is all hard bottomed reef habitat (within 1- 30 m depth), which is stratified using three depth zones (shallow [1–6 m], moderate [6–18 m], and deep [18–30 m]) and three reef zones (forereef, backreef, and lagoon). The number of sites in each strata are allocated based on the area of reef found in each of the strata and the variance within each strata.

The random stratified sampling locations are determined prior to each cruise using geographic information system (GIS) maps of bottom substrate type (hard/soft) and bathymetry. These 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 also using knowledge gained from previous visits to the survey locations. Survey sites are randomly allocated for each stratum, with 100 m minimum distance between REA sites, using the Create Random Points tool in ArcGIS (ESRI, Redlands, Calif.).

Primary and alternate survey locations (REA sites) are generated 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 3-letter island code and a 3-number site code), along with the letter *A* (e.g., TUT-112A for a site at Tutuila Island in American Samoa). Alternate survey locations are designated by the letter B following the 3-letter code.

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 this is not possible, divers attempt to drop directly from the waypoint and descend to the predetermined depth. The area to be surveyed must contain a minimum of 50% hard bottom habitat, which may necessitate some searching underwater by a dive team. If a suitable site cannot be reached within 1 min (Fig. 1), the dive should be aborted, and the team should relocate to the next site or to an alternate site. The GPS coordinate for the unsuitable site (e.g., Fig. 2) should be recorded on the Dive and Navigation Information Sheet (Fig. 36) and listed as unsurveyable, either as sand, halimeda flat, too deep, or other.



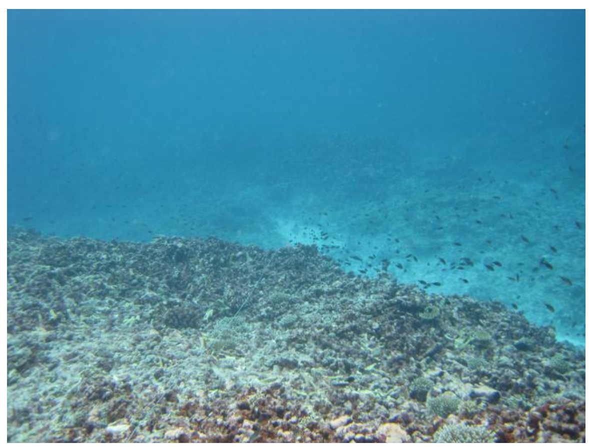


Figure 1. --Examples of suitable habitat. *NOAA photos*

Figure 2. --Examples of unsuitable habitat. *NOAA photos*

COLLECTING FISH DATA

The method used by CREP 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*. Divers record fishes underwater using a set of rules similar to those outlined by Bohnsack and Bannerot (1986), and described in detail below. Prior to each dive, divers enter the date, their initials (3-letter code used in the database), initials of buddy (3-letter code), the number of which dive they are on for that day, and dive site ID on a Fish and Habitat data sheet (Fig. 3). If the diver will be taking benthic photos, he will check the “Photographer” box and include the number of the camera being used, and if a diver is less experienced (less than 30 fish surveys dives performed), he should check the “Training” box.

Date: _______ Diver: _________ Training ☐ Photographer ☐ Camera #: ______ Site: _____________

Dive #: ____ Buddy: _____ Visibility (m): ________ Current: None Slight Mod High

SPC start time: ________ SPC end time: _________	Transect Depth (m): __________ (center of your cylinder)	Substrate slope depth (m) Top: __________ Bottom: _______

Mobile Predators	5-10 min.
Parrots	
Surgeons	
	10-30 min.
Triggers	
Butterflies	
Goats	
Groupers	
Wrasses	
Angels	Pres.
Damsels	
Others	NOTES:

Habitat type √		Substrate Height	Urchins		Benthic Cover
(Encompasses entire area)		< 20 cm _____%	Free √	Boring √	Hard Coral ____%
		20 cm - 50 cm _____%			Uprt Mac Algae ____%
1. AGg Reef	6. Pvmnt w/Snd Chnls	50 cm -100 cm ____%	D (>100)	D (>500)	CCA ____%
2. Agg Patch Reef	7. ROck/Boulder	100 cm-1.5 m _____%	A (51-100)	A (251-500)	Sand ____%
3. Agg Patch ReefS	8. Reef RuBble	> 1.5 m _____%	C (21-50)	C (101-250)	Other ____%
4. PAVmnt	9. Spur And Groove	TOTAL 100%	O (6-20)	O (26-100)	TOTAL 100%
5. Pvmnt w/Ptch Reefs	10. Snd w/Sct Coral/Rck	Max. vert. relief ____m	R (<5)	R (<25)	

Figure 3.--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, the buddy team reels out a 30-m transect line along a depth contour. After the transect line has been placed, the two divers move to the 7.5-m and 22.5-m marks, which serve as the center of their respective SPC cylinders (Fig. 4). Our standard procedure is for each site to be surveyed by one dive pair, but on rare occasions, sites may be surveyed by two teams conducting two separate counts at the same site. 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.

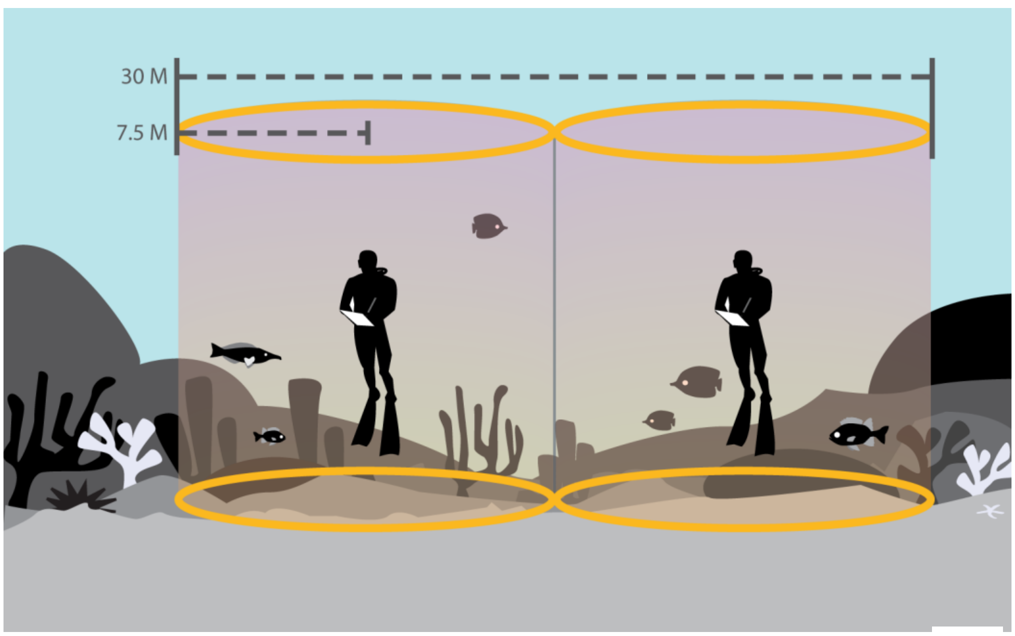


Figure 4.--Diagram of divers conducting an SPC survey at an REA site.

Fish Surveys

Fish surveys in the SPCs consist of two main components: an initial 5-minute species **enumeration period**, in which divers record all species present in or passing through their cylinders; and a subsequent **tallying period**, in which divers systematically work through their species lists successively recording the number and size (total length, TL, to nearest cm) of all fishes on their species list. The tallying portion is conducted as a series of rapid visual sweeps of the plot, with one species-grouping counted per sweep (more detail below). A species grouping is a single species or a set of species that are easily counted at the same time during one sweep (i.e. species have similar search image and are similarly distributed: e.g., large groupers, benthic-associated damselfishes, small parrotfishes). Divers use their own judgment on groupings to maximize survey efficiency without compromising data quality. For example if few benthic-associated surgeonfishes are present in a cylinder they may all be counted in one sweep, but where one or more species are highly abundant, those species will likely be counted in their own single-species sweep.

To the extent possible, divers remain at the center of their cylinders throughout the survey. However, small and cryptic species, which will tend to be underrepresented in counts made by an observer remaining in the center of a 7.5-m radius cylinder, are left to the end of the tallying period, at which time the divers swim through their plot area searching for those species. The fish and habitat datasheets are organized such that priority species are at the top of the form, and small and cryptic species at the bottom, thus facilitating this prioritization, as divers will typically work through their species list from the top of the sheet down (Fig. 3).

In cases where a species was observed during the enumeration period but was not present in the cylinder during the tallying period for its species-grouping, divers make their best estimates of size and number observed at the time of the first encounter with that species during the enumeration period. Divers circle those observations on their data sheets, and they are recorded in the database as “non-instantaneous,” to distinguish them from the ‘instantaneous’ counts made during the rapid sweeps.

A number of rare and generally highly mobile taxa are quite frequently seen during the species enumeration 5-minute period but are not present at the time of the instantaneous sweep of their species group. For those fish, divers generally note the number and size of fishes of those taxa at the time they are first observed in the cylinder during the species-enumeration period. This is done to facilitate more accurate recall of numbers and sizes for when divers need to record non-instantaneous data. Only the first instance of these fish should be recorded; e.g., if a shark is recorded during the first minute of the survey and additional sharks appear two minutes later during the first 5 minutes, the second instance of the sharks during this 5-min. enumeration period should NOT be recorded. If these fish are present during the tallying portion of the survey, they should be recounted and sized, with the previous (non-instantaneous) entries for that species crossed out. Examples of such species include *Bolbometopon muricatum* (bumphead parrotfish), *Cheilinus undulatus* (humphead wrasse), *Variola louti* (lyretail grouper), *Chanos chanos* (milkfish), and *Aprion virescens* (green jobfish), and fish from the families Carcharhinidae (sharks), Carangidae (jacks), Lethrinidae (emperors), Sphyraenidae (barracuda).

Additionally, in order to increase diver’s ability to record as much information as possible during counts, divers also record number and size of fishes of species that are first encountered (i) in the first 5 minutes of the tallying portion (i.e., 5-10 minutes after the start of the count); and (ii) at any time later during the tallying portion (i.e., at least 10 minutes after the start of the count). In those cases, as soon as possible after observing the species for the first time, divers should record the number and size of all fishes of that species present in the cylinder by means of a rapid visual sweep of the entire cylinder. Species first observed after the enumeration period are typically recorded on the right hand side of the datasheet (Fig. 3), with timing noted appropriately. Divers also have the ability to record the presence of species of interest seen in the vicinity of the surveys, but not within the diver’s cylinder at any point in their count. Regional-specific lists of species of interest are issued to determine which species divers should record in this way.

There are therefore several different types of data gathered during surveys. However, these are all gathered in a consistent manner in each survey and are recorded differently in the database, allowing us to gather data on any species that comes within the cylinder in the course of the survey, or in case of species of interest, is seen in the vicinity of the surveys. Because methods are consistent and the different data types are explicitly recorded on data sheets and in the database resulting data can be filtered appropriately for any particular question or comparison. Those different data types and their ‘observation type’ codes are shown in Table 1.

Table 1--Types of data gathered during surveys.

Observation Code	Description
I	‘**Instantaneous**’ data. The species was present in or passed through the cylinder during the initial 5-minute species enumeration phase, and was also present within the diver’s cylinder at the time of the instantaneous sweep for its species-group. In most surveys, the bulk of data are recorded as ‘instantaneous’. These data are probably the most suitable for estimation of density per unit area.
N	‘**Non-instantaneous**’ data. The species was present during the 5-minute enumeration period, but not at the time of the instantaneous sweep for that species-group. In this instance, divers record their best estimate of number and size of this species present in the cylinder at the time they were first observed. Typically, divers make temporary notes of that information for taxa that are known to be mobile and/or skittish, and thus relatively frequently fall into this category.
F	‘**Five-to-ten minute**’ data. These are species that were not present within the cylinder at any time during the species enumeration period, but are observed in the first 5 minutes of the tallying portion of the count (i.e. 5-10 minutes after the start of the species-enumeration period which is the beginning of the survey). As soon as possible after noting the presence of a species in those circumstances, divers should perform a rapid visual sweep of the cylinder, recording number and size of all individuals present.
T	‘**Ten-to-thirty minute**’ data. These are fishes of species that are first observed within the cylinder during the tallying portion of the count, but at least 5 minutes into that portion of the count (i.e. 10 to no more than 30 minutes after the start of the species enumeration period). As with ‘F’ data, as soon as possible after noting the presence of a species in these circumstances, divers should perform a rapid visual sweep of the cylinder, recording number and size of all individuals of this species that are present in the cylinder. Because the length of the tallying portion varies among counts, it will be problematic to use ‘T’ data for any measure of relative abundance, but data can still have value for example as a contribution towards a species’ size-distribution.
P	‘**Present**’. These are species observed in the vicinity of but not within the divers’ cylinders during survey. As described above region-specific lists are used to determine whether species are of sufficient interest to be recorded as ‘present’ or not at a particular location. It is up to the discretion of the diver to determine whether they can accurately estimate the size of individuals observed in the presence category, given the distance the species is from the diver and water visibility conditions. Divers should weigh their confidence in accurately estimating the size of species recorded in the presence category as these data are used to gather size composition information used to estimate exploitation rates for target species (see Nadon 2015). If their confidence is low, species should simply be recorded as present without size estimates.

'Instantaneous' Counts--Using Rapid Visual Sweeps

To the extent possible, 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. 5). 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.

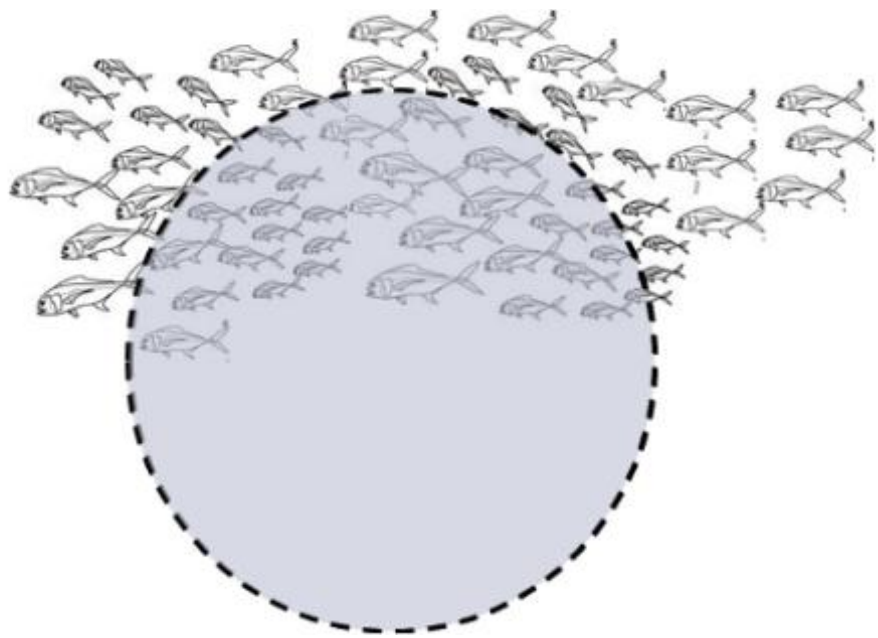


Figure 5.--A snapshot of a large school of fish as it swims through a cylinder. Only the fish in the shaded portion, which illustrates a visually estimated cylinder, should be counted.

After each fish survey is completed and just before beginning to collect benthic data, divers should record the end time on the data sheet (Fig. 3).

Sizing Fishes

Fish size should be estimated to the nearest centimeter for total length, defined as the length from the tip of the snout to the tip of the longer lobe of the caudal fin (Fig. 6). Total length for rays (Myliobatidae) is measured from pectoral fin tip to pectoral fin tip (Fig. 7).

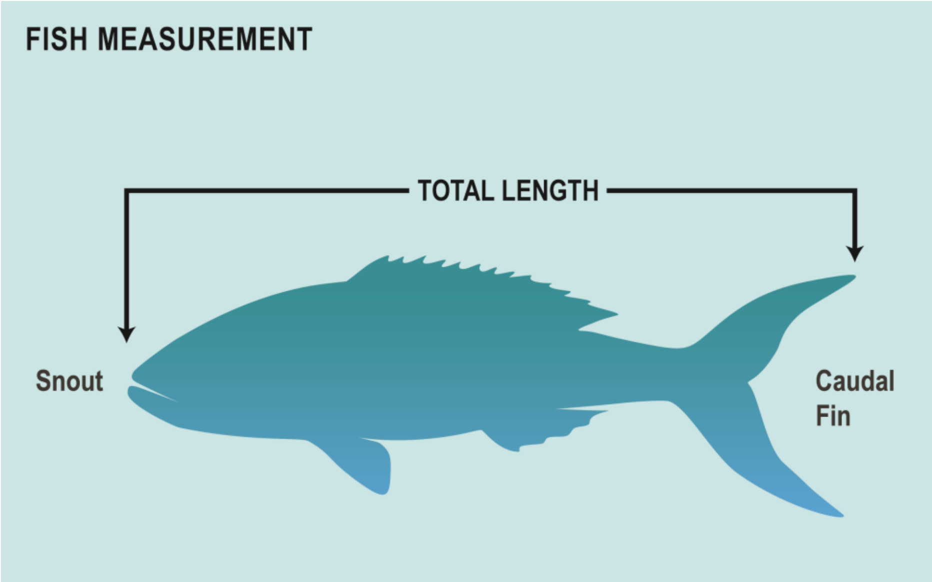


Figure 6.--Illustration of total length measurement.

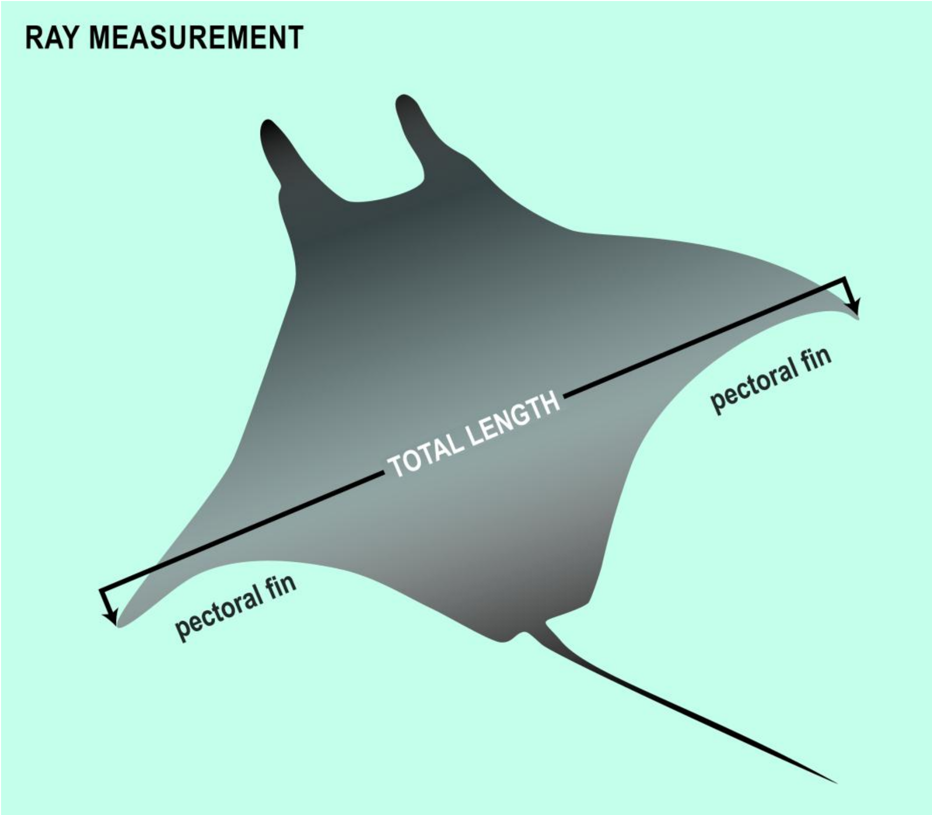


Figure 7.--Illustration of total length measurement for rays.

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

General Notes on Fish Counts

Cryptic species: While divers should attempt to survey all species within their cylinders, certain species – such as small blennies and gobies and other cryptic or semi-cryptic species – are not generally well surveyed by this kind of all-purpose visual survey method. To the extent data on species as blennies and gobies is used, it will be generally be for presence absence or for assemblage richness, and even in the best of circumstances, it is likely that the quality of that data will vary among observers. Divers are therefore advised that too much focus on these small and cryptic species can detract from their ability to properly record the numbers and sizes of the larger-bodied and more conspicuous species that comprise the bulk of biomass, and encompass the majority of species targeted by fisheries.

In cases where a diver has strong reason to believe that a species only observed late in the dive was very likely present during the species enumeration period, but was missed – e.g., cryptic or relatively sedentary species, for example a grouper that emerges from a hole in the reef, or soldierfish under a ledge (Fig. 8) – divers are directed to treat data from that species as 'instantaneous' data (i.e., assumption is that the fishes were present continuously during the survey of that cylinder and hence were really present during the enumeration period and at the time that that species visual sweep would have occurred).

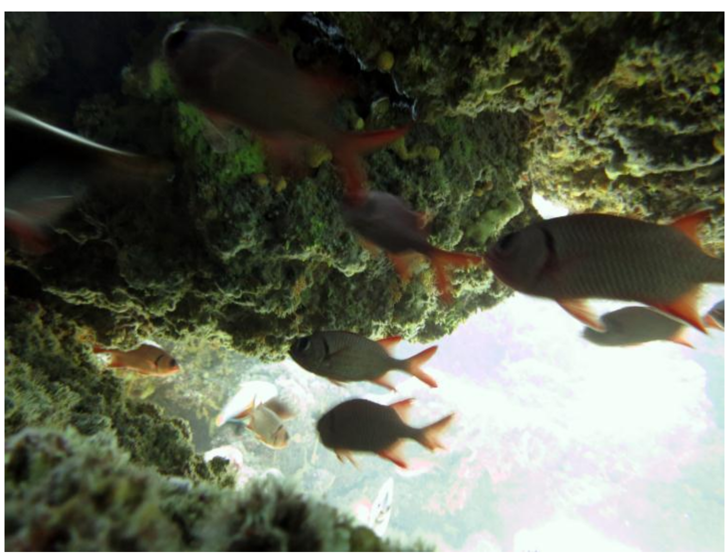


Figure 8. -- Soldierfish under a ledge that were not seen during the initial 5-min. of the survey. These fish should be included as "instantaneous." *NOAA photo*

It can be extremely challenging to survey small, abundant and semi-cryptic species in a large sample area (e.g. a diver's 15-m diameter cylinder). For those species only, if the survey habitat is relatively homogenous, divers are allowed to sub-sample the cylinder and extrapolate counts for those particular species (e.g. survey half the cylinder and double the counts).

Terminal-phase parrotfishes: In the Hawaiian Islands, terminal-phase parrotfishes should be distinguished from juvenile- or initial-phase parrotfishes by writing a *T* next to the size on the data sheet. Outside of the Hawaiian Islands, terminal phases of some species of parrotfishes are often indistinguishable from initial phases, so this notation is not attempted.

Dive safety considerations: Survey divers in buddy pairs remain in visual contact with each other at fixed locations along the transect line as they implement circular scans of their respective survey areas. For SPC surveys, NOAA PIFSC dive rules require divers to carry a reserve air supply system (RASS) on dives deeper than 6m. Divers must carefully monitor their own and each other's air supply and communicate tank pressures 10 and 20 minutes 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. 9). 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.

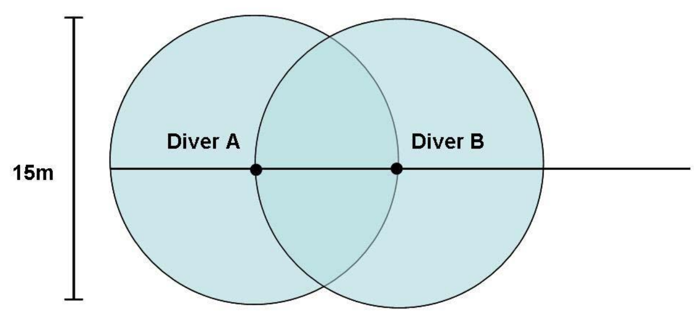


Figure 9.--Overhead view of a transect layout using overlapping SPC cylinders.

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, habitat complexity, and urchin abundance, and recording them at the bottom of the Fish and Habitat data sheet (Fig. 10). Benthic photos are taken at 1m intervals along the entire 30-m transect line, and site photos are taken of the survey area. The total time for estimating benthic cover should be no more than ~ 5 min. If the diver is inexperienced at making these estimates, they should use the data from their more experienced buddy until they feel more comfortable with gathering this data.

Habitat type √		Substrate Height	Urchins		Benthic Cover
(Encompasses entire area)		< 20 cm _____%	Free √	Boring √	Hard Coral ____%
		20 cm - 50 cm _____%			Uprt Mac Algae ____%
1. AGg Reef	6. Pvmnt w/Snd Chnls	50 cm -100 cm _____%	D (>100)	D (>500)	CCA ____%
2. Agg Patch Reef	7. ROck/Boulder	100 cm-1.5 m _____%	A (51-100)	A (251-500)	Sand ____%
3. Agg Patch ReefS	8. Reef RuBble	> 1.5 m _____%	C (21-50)	C (101-250)	Other ____%
4. PAVmnt	9. Spur And Groove	TOTAL 100%	O (6-20)	O (26-100)	TOTAL 100%
5. Pvmnt w/Ptch Reefs	10. Snd w/Sct Coral/Rck	Max. vert. relief ____m	R (<5)	R (<25)	

Figure 10.--Areas where benthic data are recorded on the Fish and Habitat data sheet.

Benthic Cover

Percentages of non-motile benthic cover are estimated from an aerial (planar) view for five categories: hard corals, upright macroalgae, crustose coralline algae (CCA), sand and other (i.e. everything else). Percentages should total 100%. The five categories are defined below:

Hard Corals are characterized by coral colonies or portions of colonies that are covered with living tissue. Living tissue usually appears colored due to the presence of pigments in coral tissue and/or their symbiotic zooxanthellae. Morphologies for hard corals can range from branching, foliose, columnar, massive, free-living, and encrusting (Fig. 13). Examples are the genera *Porites, Montipora, Acropora, Pavona*.

Figure 13.--Examples of hard coral. *NOAA photos*

Upright Macroalgae are algae that do not form crusts adherent to rubble or the substrate and are visible to the naked eye (typically > 1 cm), with evident complex structure, i.e., distinct leaves, blades, ferns, feathers, balls, branched shrubs, etc. (Fig. 14). Examples are the genera *Halimeda, Microdictyon, Dictyota, Liagora.*

Figure 14.--Examples of upright macroalgae. *NOAA photos*

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 three dimensional spires (Fig. 15). The crustose red algae from the family Peyssonneliacae may be included in this category.

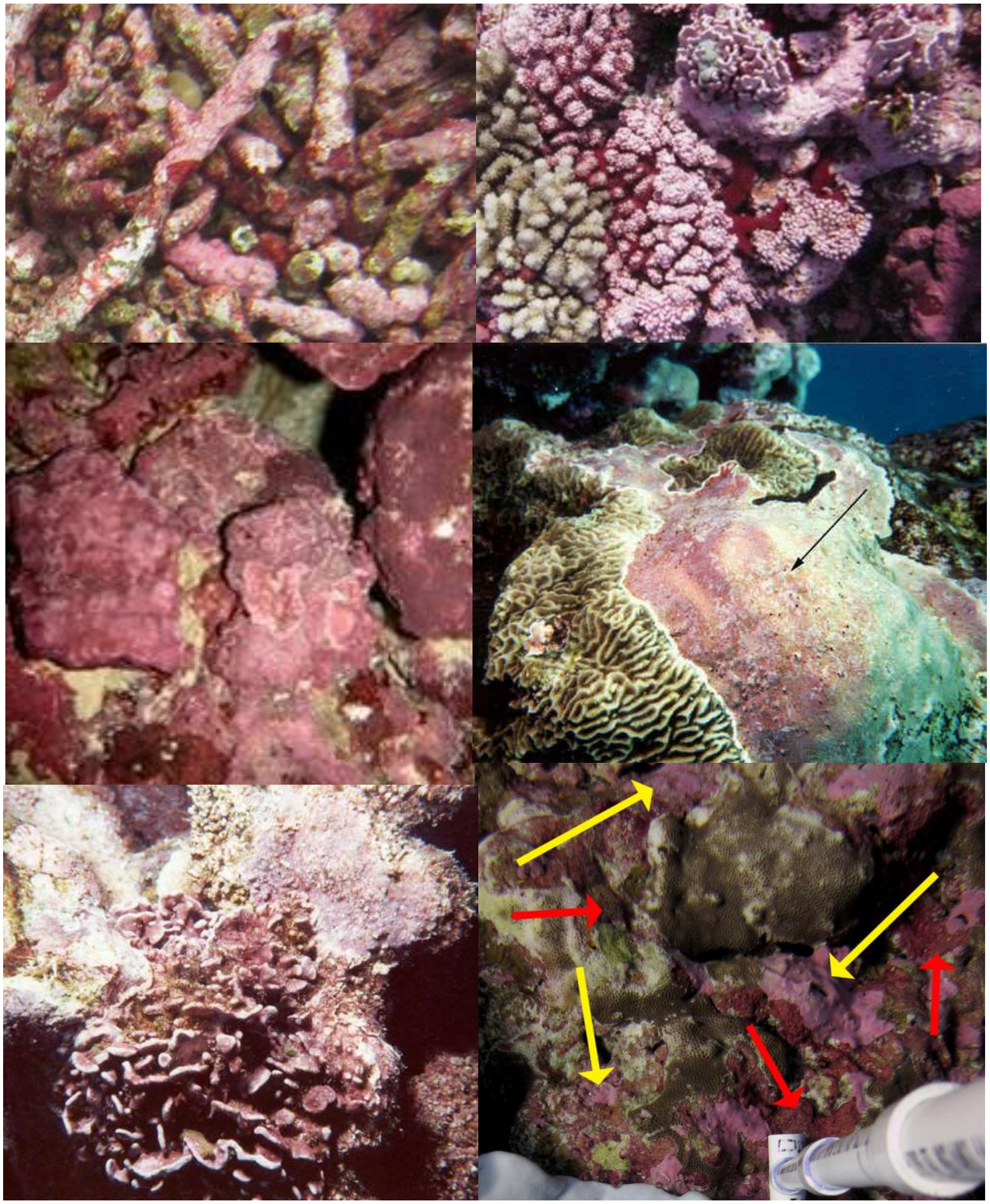


Figure 15.--Examples of crustose coralline algae and crustose red algae. *NOAA photos*

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, generally > 1 cm deep. (Fig. 16)

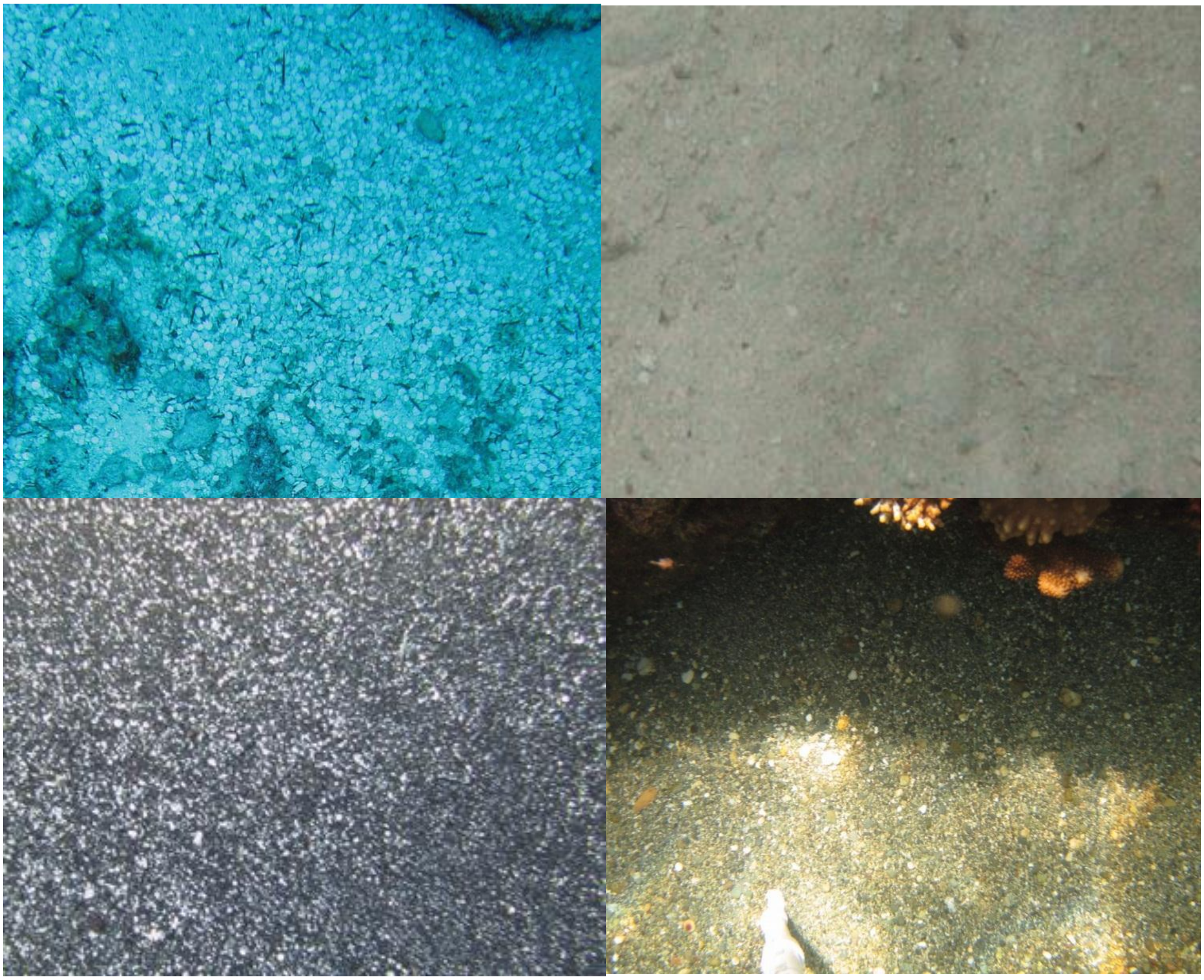


Figure 16.--Examples of sand. *NOAA photos*

Other is a category encompassing all other biotic organisms making up the remainder of the survey area not inhabited by hard coral, upright macroalgae, CCA, and sand. It can include turf algae, cyanobacteria, soft corals, zoanthids, sponges, anemones, etc. (Fig. 17). It does not include mobile invertebrates such as sea urchins, sea stars, or sea cucumbers.

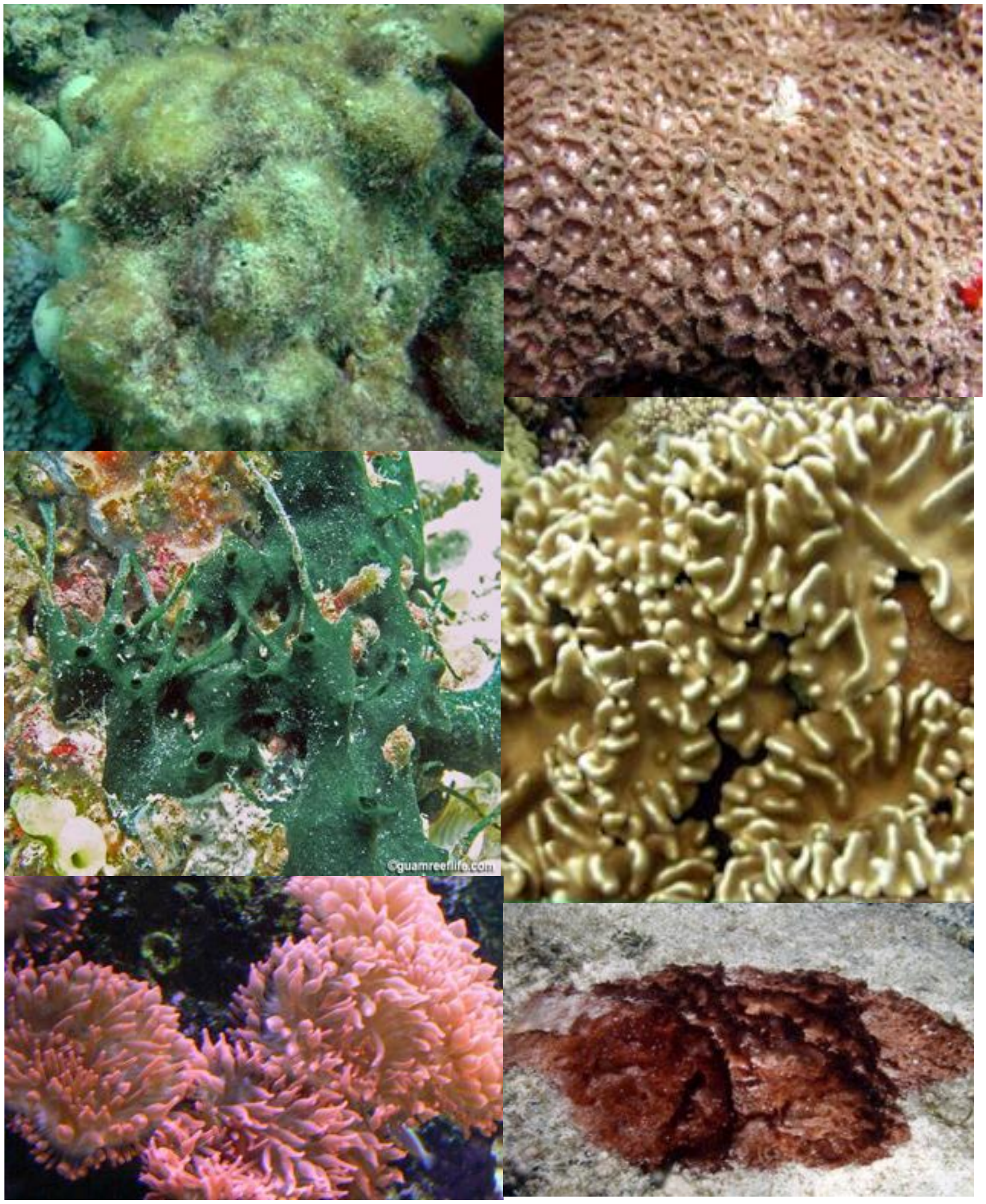


Figure 17.--Examples of organisms classified under “Other.” *NOAA photos*

Habitat Type

Reef (or habitat) type is characterized by selecting the most appropriate choice that describes the habitat making up the general survey area; it is not relegated to only the diver’s survey cylinder: Aggregate reef, Aggregate patch reef, Aggregate patch reefs, Pavement, Pavement with patch reefs, Pavement with sand channels, Rock/boulder, Reef rubble, Spur and groove, and Sand with scattered Coral/Rock (Fig. 10). Because of the great variety of reef habitats comprising ecosystems around the many Pacific islands surveyed by CREP, 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. At the surface, the diver should discuss questionable habitat types with their buddy and come to a consensus. The agreed-upon habitat type will be entered in the Dive and Navigation Information Sheet (Fig. 36).

The categories for habitat type are modified from Kendall M.S. and M. Poti, 2011.

Pavement: Flat, low-relief, solid rock in broad areas often with partial coverage of sand, algae, hard coral, gorgonians, zooanthids, or other sessile invertebrates that are dense enough to begin to obscure the underlying surface (Fig. 18).

Figure 18.--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. 19). 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 19.--Example of spur-and-groove habitat. *NOAA photo*

Aggregate Reef: Hard-bottom substrate with corals, also referred to as continuous or consolidated reef (Fig. 20). This habitat type may have high relief but lacks the sand or pavement channels of Spur and Groove. Most reefs that do not obviously fall in other types are recorded as Aggregate reef.

Figure 20.--Example of Aggregate reef. *NOAA photo*

Rock/Boulder: Large, irregularly shaped carbonate blocks or boulders or volcanic rock often extending offshore from the island bedrock or headlands. Can also occur as aggregations of loose rock fragments that have been detached and transported from their native beds. Individual boulders often range in diameter from .25 – 3 m, with very little benthic cover present (Fig. 21).

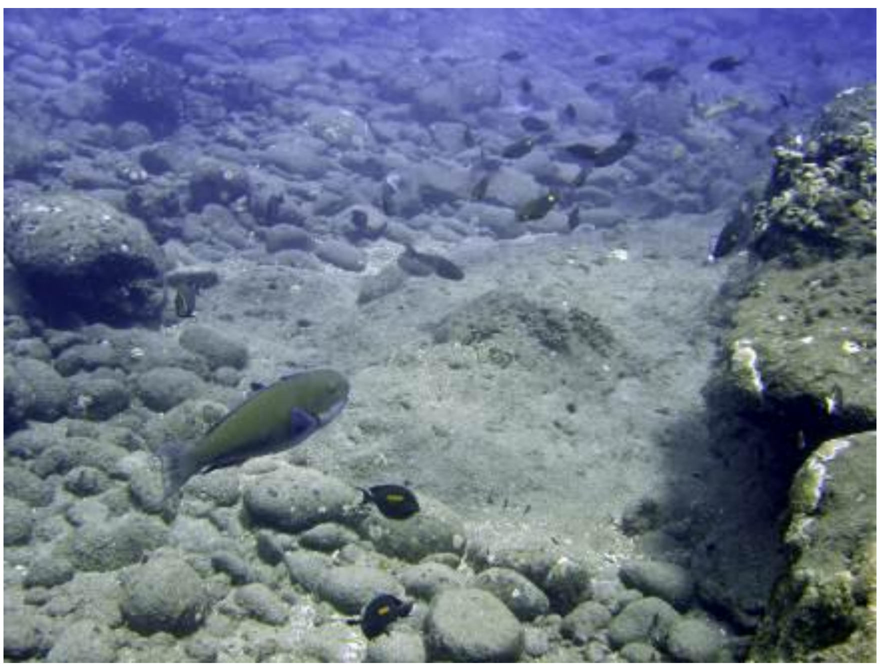


Figure 21.--Example of rock/boulder habitat. *NOAA photo*

Reef rubble: Unconsolidated small (< 10 cm) fragments of coral skeletons or reef rock often colonized with filamentous or other macroalgae (Fig. 23). This habitat often occurs landward of well-developed reef formations in reef crest or backreef zones.

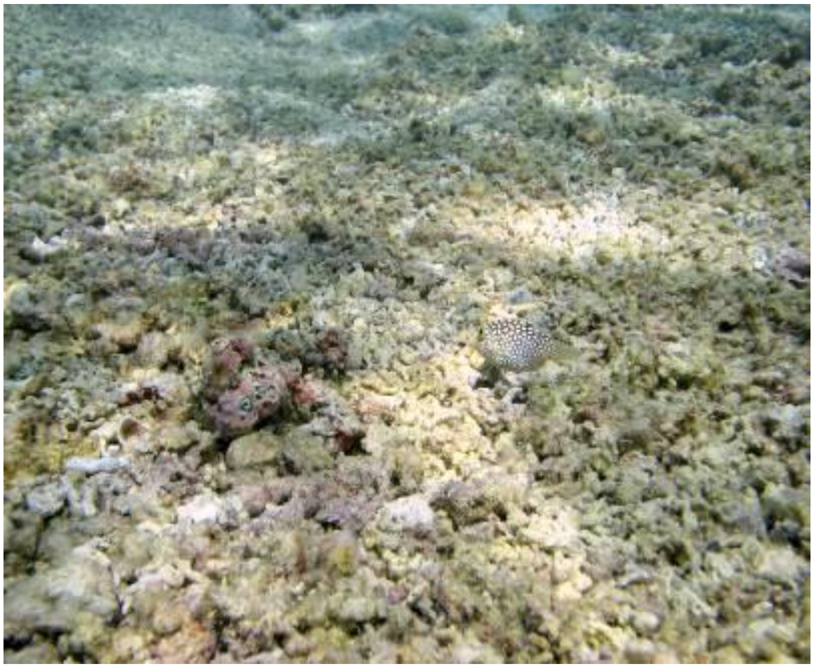


Figure 22.--Example of rubble habitat. *NOAA photo*

Aggregate Patch Reef: May also be referred to as Individual Patch Reef. Coral formations that are isolated from other coral reef formations by sand or other habitats and that have no organized structural axis relative to the shore or shelf edge. They are characterized by an often circular or oblong shape with a vertical relief of one meter or more in relation to the surrounding seafloor and are larger or equal to the general survey area 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. 23) shows a number of patch reefs in southern Kāne`ohe Bay, O`ahu, Hawai`i.

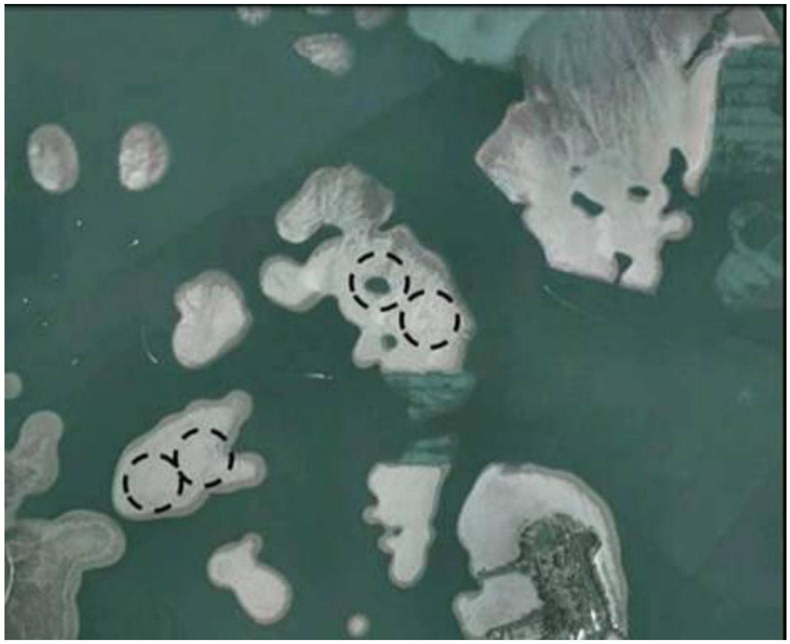


Figure 23.--Aerial view of patch reefs in southern Kāne`ohe Bay, O`ahu, Hawai`i. Black circles denote how stationary point counts would be laid out on such reefs. © 2011 Google and satellite imagery © 2011 DigitalGlobe, GeoEye, and U.S. Geological Survey.

Aggregate Patch Reefs: These features have the same defining characteristics of an Aggregate (Individual) Patch Reef but are clusters of smaller patch reefs that cover > 10% of the survey area (Fig. 24).

Figure 24.--Example of Aggregate Patch Reefs habitat. *NOAA photo*

Pavement with Patch Reefs: Areas of pavement with occasional patch reef formations that make up less than 10% of the general area (Fig. 25).

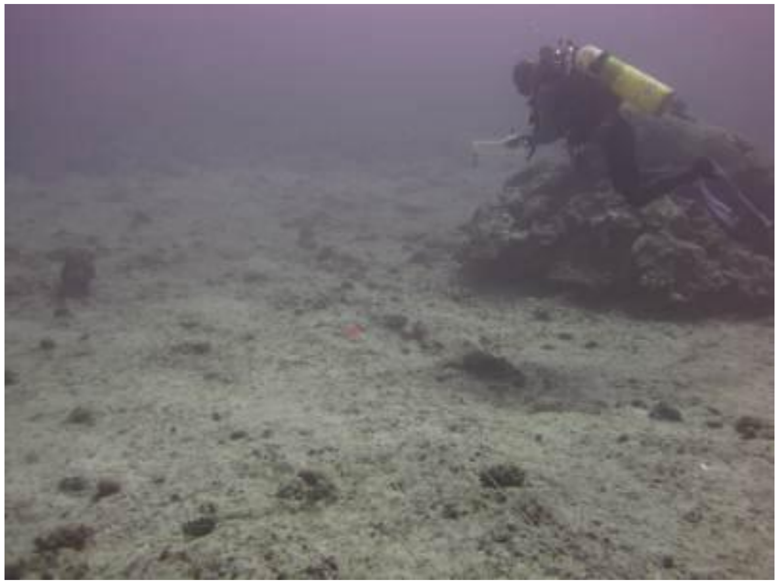


Figure 25.--Example of Pavement with Patch Reefs habitat. *NOAA photo*

Pavement with Sand Channels: Habitats of pavement with alternating sand/surge channel formations that are perpendicular to the shore, bank, or shelf (Fig. 26). The channels of this feature have low vertical relief relative to spur and groove formations and are typically erosional in origin. This habitat type occurs in areas exposed to moderate wave surge.

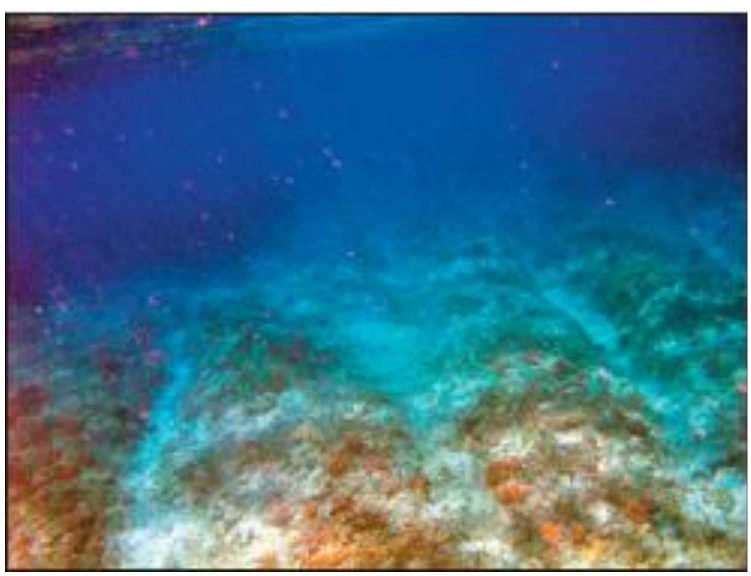


Figure 26.--Example of Pavement with Sand Channels habitat.
NOAA biogeo photo

Sand with Scattered Coral/Rock: Sand bottom with scattered rocks or small, isolated coral heads that make up < 10% of the total area (Fig. 27).

Figure 27. Example of Sand with Scattered Coral and Rock habitat. *NOAA photo*

Note that, survey protocol is to aim to survey only in habitats with > 50% hardbottom. Therefore, surveys should not normally be conducted in sand habitats. However, where substrate is hard bottom with a light but consistent cover of sand, it is still acceptable to survey in that habitat, and typically those surveys will be recorded in this habitat class.

Substrate Height (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: < 20 cm, 20 cm – 50 cm, 50 cm – 100 cm, 100 cm – 1.5 m, and > 1.5 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 meter stick, which is marked in 10-cm increments, can be used as an aid in measuring complexity (Figs. 28-29). Maximum vertical relief is measured as the greatest height change in the cylinder.

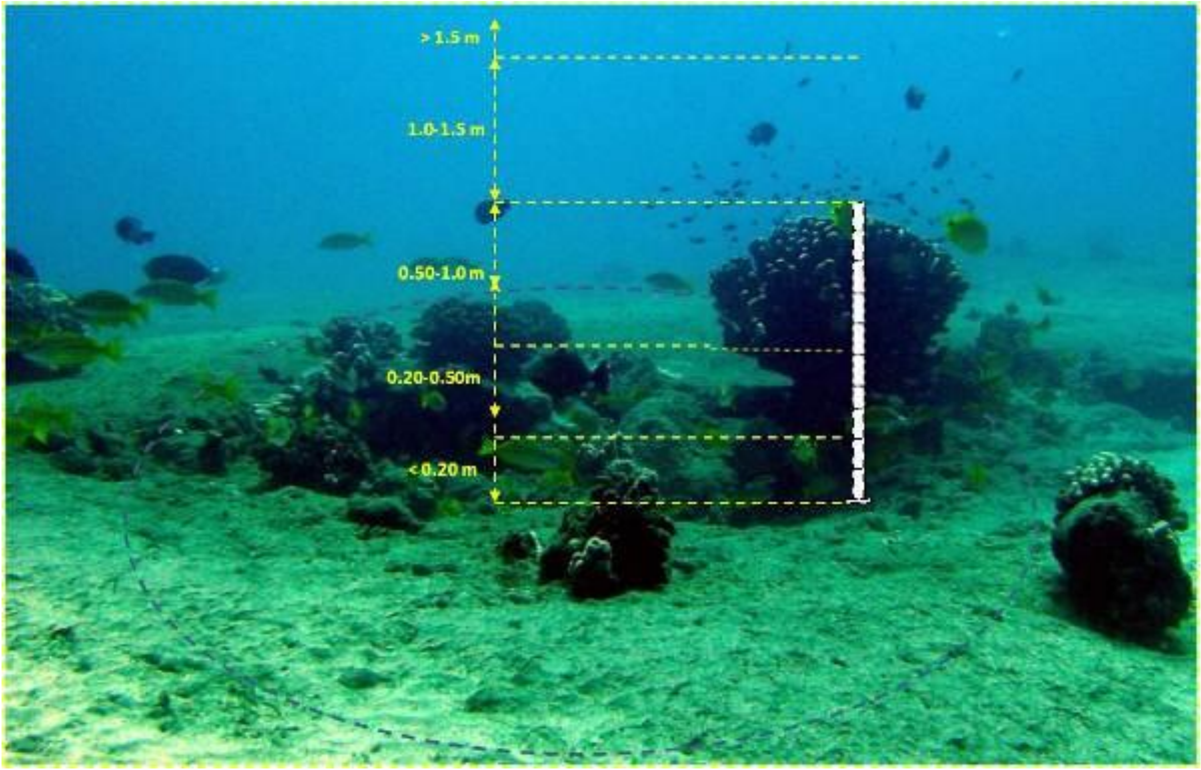
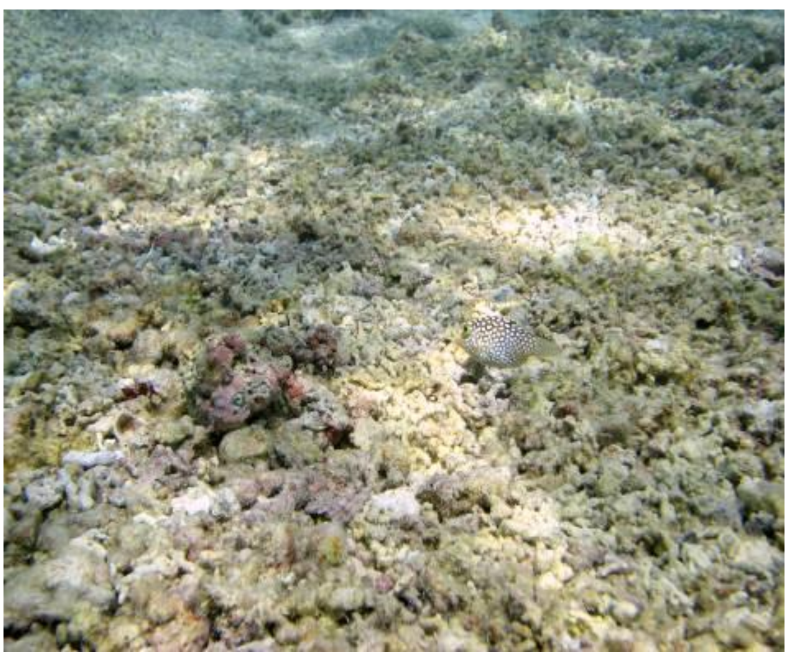


Figure 28.--Example of estimating substrate height and maximum vertical relief using vertical height categories. *NOAA photo*



Substrate Height	
< 20 cm	100 %
20 cm - 50 cm	____%
50 cm -100 cm	____%
100 cm-1.5 m	____%
> 1.5 m	____%
TOTAL	100%
Max. vert. relief	.1 m

Figure 29.--Example of estimating substrate height and maximum vertical relief. *NOAA photo*

Urchin Abundance

Urchin abundance is estimated within each cylinder using the DACOR system (D = Dominant, A = Abundant, C = Common, O = Occasional, R = Rare) (Fig. 10). Each diver makes a visual sweep of their cylinder, estimating the number of spiny urchins and rock boring urchins present. Spiny – or "free" – urchins include species from the genera *Tripneustes*, *Heterocentrotus*, *Diadema*, and *Echinothrix* (Fig. 30) and are quantified as D (> 100), A (51-100), C (21-50), O (6-20), R (< 5). Boring urchins include species from the genera *Echinometra* and *Echinostrephus* (Fig. 31) and are quantified by the DACOR as D (> 500), A (251-500), C (101-250), O (26-100), R (< 25).

Figure 30.--Examples of 'free-living' urchins.

Figure 31.-- Examples of boring urchins.

Sample-specific data

The following sample-specific data also should be recorded at the top of the of the Fish and Habitat data sheet (Fig. 3):

Bottom Current: Estimated using four categories: None (no current), Slight (diver feels the presence of current but is able to stay in the same position with minimal or no kicking), Mod (diver is able to stay in the same position with gentle to moderate kicking), High (diver struggles to stay in the same position). Current should not be confused with bottom surge.

Visibility: Horizontal visibility, in meters, estimated at survey site by divers using a Secchi disk.

Transect Depth: Depth (m) taken at the midpoint of a diver's cylinder.

Slope: Divers record the minimum (Top) and maximum (Bottom) depths (m) within their cylinder, meaning the minimum and maximum depths on an imaginary plane underlying the survey cylinder (Figs. 32 and 33). If there is no slope, the minimum and maximum depths will be the same (Fig. 33). If it is not possible to measure depths at the top and bottom edges of the cylinder – e.g., due to air supply or allowable dive time or depth limits, they may be estimated rather than measured.

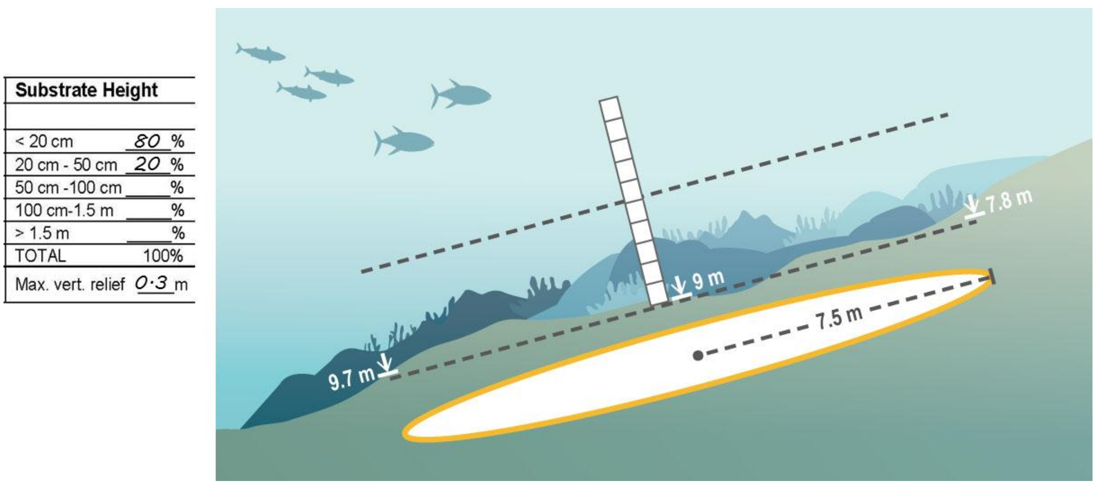


Figure 32.--Measuring slope for sample-specific data collection.

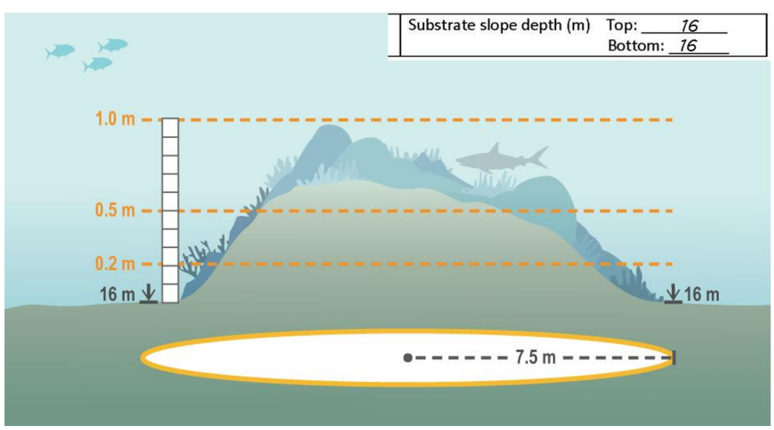


Figure 33.--If there is NO slope then Top = Bottom.

Additional Replicates: While CREP does not typically do this, if there is sufficient bottom time and breathing gas supply, a second SPC-survey may be conducted by the dive pair after completion of the first SPC survey. In those cases, the dive pair should mark the first replicate as "REP A" on their data sheet, recover the 30-m transect line at the end of the first count and move to another area of reef and from there repeat the entire procedure is repeated with data recorded on a new data sheet, with the second replicate marked as "REP B" To the extent possible, the transect line should be relocated at the same or similar depth, and at least 20 m away from the boundary of the original SPC survey area. Analysis of previous data has indicated that it is generally optimal to aim to maximize the number of sites surveyed in a day, rather than to conduct replicate counts at each site. Therefore, it is recommended for CREP surveys that two replicates are only completed at a site in situations where the increased survey time at that site does not reduce the total number of sites that can be surveyed by a team in a day.

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, no less than four photos are taken to show the general habitat in each cylinder (Fig. 34). 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 meter stick, to allow photos to be taken at a fixed height (1 m) above the sea floor. 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.

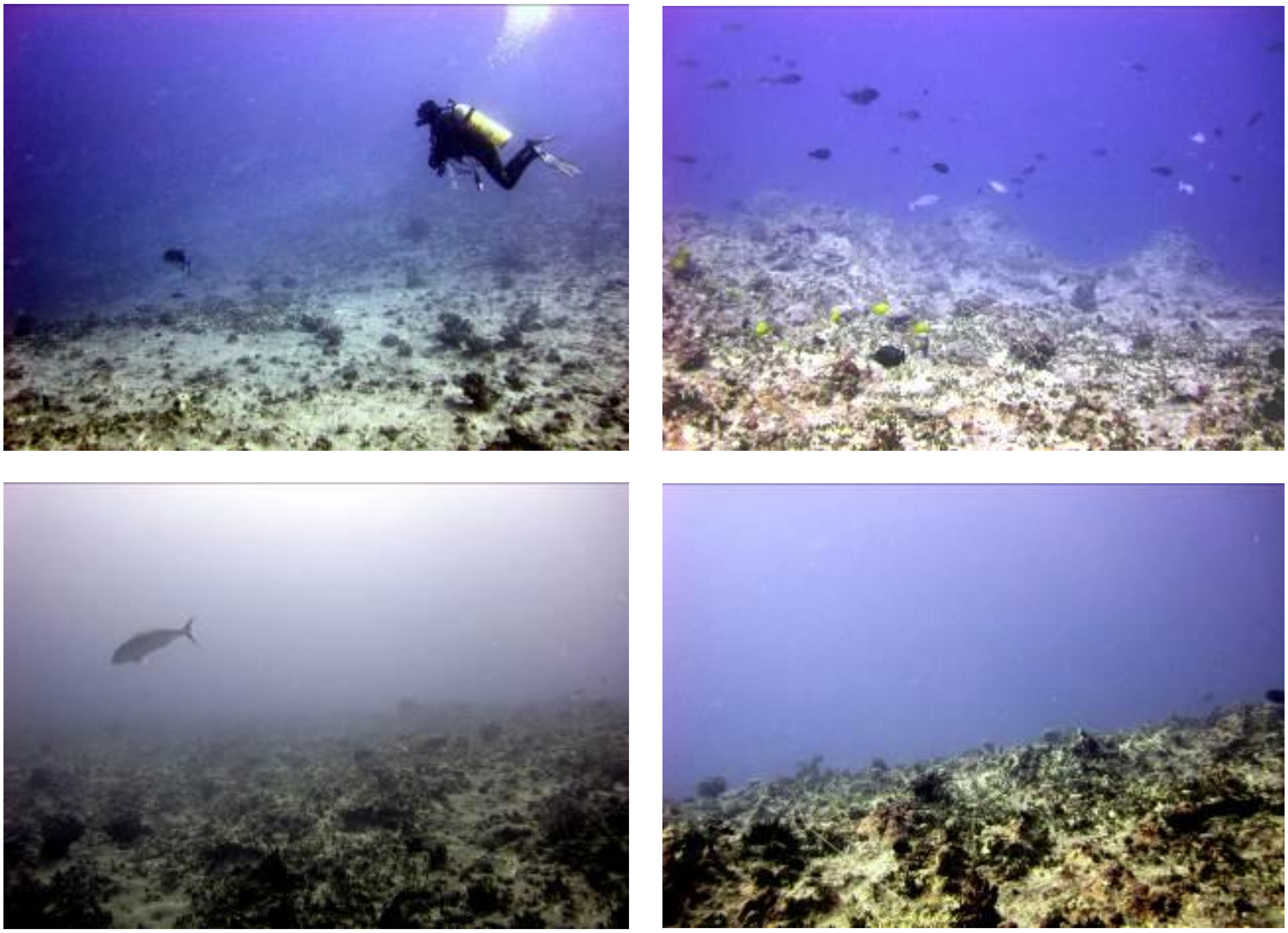


Figure 34.--Examples of site photos taken after SPC surveys. *NOAA photos*

The diver-photographer should look at the camera viewfinder during and after taking pictures to ensure that orientation of the monopod is correct (Fig. 35) and that the image is not blurry.

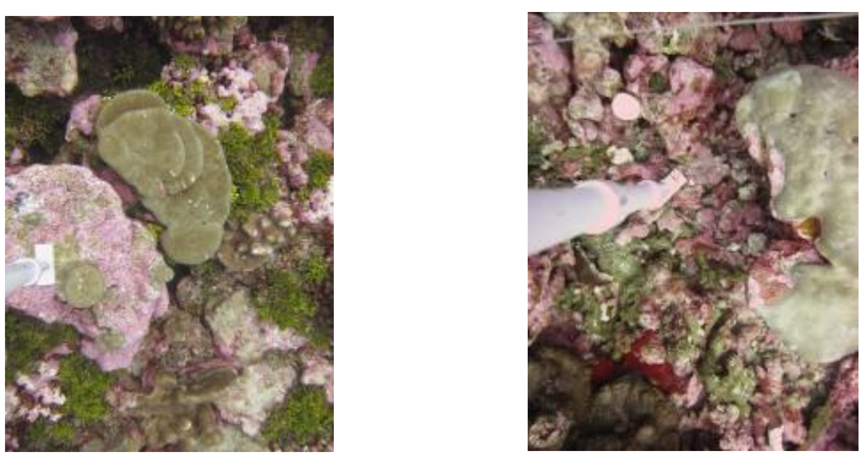


Figure 35.--Examples of (*a*) ideal and (*b*) incorrect monopod placements. *NOAA photos*

If the meter stick is crooked (Fig. 35 [b]), an object is in the way, or the image is blurry, another photo should be taken and the original photo deleted. If the bad photo is not deleted in the field, it should be deleted once the camera is downloaded.

DIVE AND NAVIGATION INFORMATION

The Dive and Navigation Information form (Fig. 36) is used to record the location of fish REA 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)
- **Local Time Zone (example)**: PST (Pacific Standard Time)
- **Local Time = UTC +/- (example)**: + 10 hours
- **Small Boat**: Current small dive boat (e.g., Rubber Duck, HI-3)
- **Cruise ID**: The 6-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
- **Island 3-ltr Code**: The 3-letter island code (e.g., TUT)
- **Site ID (# only)**: The 4- or 5-digit code for current site (e.g., 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* (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 coordinates saved under the Waypoint Number.
- **Zone Type**: Forereef (F), backreef (B), or lagoon (L).
- **Depth Strata**. Recorded as shallow (S), moderate (M) or deep (D). Can be abbreviated as S, M or D. Transect Depth is captured by each diver on the underwater data sheets (Fig. 4).
- **Habitat type**: Either taken from the Fish and Habitat Data Sheet (Fig. 4), or, if the site is determined to be unsurveyable because of unsuitable habitat or depth, the designations Sand, Halimeda, too deep, or Other will be used. The habitat codes are listed at the bottom of the Dive and Navigation Information form (Fig. 36).
- **Benthic Photos**: Initials of the diver that took benthic photos.
- **Camera #**: The number of the camera assigned to the person taking benthic photos.
- **Diver #1 (or #2) (initials) PSI in/out:** Initials of the diver participating in the survey, along with his/her tank pressure before the dive, and then after (e.g., PMA 3000/1100)
- **Additional Notes**: This space can be used to record any additional information judged to be important by data collectors.

Island: ______________________
Local Time Zone: ______________________
Local Time = UTC +/- ______ Hours

Dive and Navigation Information
Coral Reef Ecosystem Division
NOAA Pacific Islands Fisheries Science Center
Fish REA

Small Boat: ______________________
Cruise ID: ______________________
Survey Year: ______________________

Local Date	Local Time	Island 3-ltr Code / Site ID (# only)	GPS Unit #	Waypoint #	Dive #	Latitude (N/S 00.00000)	Longitude (E/W 00.00000)	Zone Type (forereef / backreef / lagoon)	Depth strata (Shallow/Mid/Deep)	Habitat type (see codes below)	Benthic Photographer (initials)	Camera #	Diver #1 (initials) PSI in/out	Diver #2 (initials) PSI in/out

Additional Notes:

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

Habitat types: Agr Reef (**AGR**), Agg Patch Reef (**APR**), Agg Patch ReefS (**APS**), PAVmnt (**PAV**), Pvmnt w/Ptch Reefs (**PPR**), Pvmnt w/Snd Chnls (**PSC**), Rock/Boulder (**ROB**), Reef RuBble (**RRB**), Spur And Groove (**SAG**), Snd w/Sct Coral/Rck (**SCR**)
Unsampleable areas (survey dive not made): Sand (**USS**), USH - Halimeda (**USH**), too deep (**USD**), Other (**USO**)

Rev'd 10/28/2014

Figure 36.--Sample Dive and Navigation Information form used for diving activity at fish REA sites.

ARCHIVING PHOTOS

After each day's field operations, benthic images are uploaded to the data server and must be stored in the following file folder format. A directory is designated on the shared drive for storing all benthic photos. Directory organization, for example, should follow the one also used on the main CREP 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 benthic photos (images taken along transects) or site photos (e.g., 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 photos are correctly catalogued.

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 which is stored on the ship's data server. The name of this database carries a prefix for the current cruise (e.g., HA1008 CREP Fish-TDS Database.mdb). Data entry should follow the methods outlined in the forthcoming report titled, "Coral Reef Ecosystem Program 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 datasheet.

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