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Ecosystem Sciences Division Standard Operating Procedures: Data Collection for Rapid Ecological Assessment Benthic Surveys, 2018 Update

Morgan Winston, Courtney Couch, Marie Ferguson, Brittany Huntington, Dione Swanson, and Bernardo Vargas-Ángel



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Introduction

This 2018 document update is intended as a reference and provides guidelines for training, sampling, and data entry for the monitoring of coral populations and benthic communities as part of the Pacific Reef Assessment and Monitoring Program (Pacific RAMP) led by the Ecosystem Sciences Division (ESD) of the NOAA Pacific Islands Fisheries Science Center (PIFSC). The standard operating procedures (SOP) outlined in this document apply to the Pacific RAMP surveys that ESD and its partners conducted in 2018 on the coral reef ecosystems of American Samoa and the Pacific Remote Island Areas Marine National Monument (Palmyra and Kingman Atolls, and Howland, Baker, and Jarvis Islands). As part of ESD's ecosystem assessment and long term monitoring efforts, coral colonies and the benthic community functional groups are surveyed at Rapid Ecological Assessment (REA) sites selected using a stratified random sampling design. The details of the methods employed are outlined in this report.

Objectives

The objective of this document is to provide updates incorporated in 2018 to the guidelines and procedures for implementation of sampling design, survey methodology, and data entry for the monitoring of reef coral populations and benthic communities as part of the Pacific RAMP led by ESD (Swanson et al. 2018).

The two primary objectives of the monitoring effort are: (1) to determine status, trends, and variability of coral populations and (2) to determine status, trends, and variability in benthic reef coral communities. Measured and generated coral population metrics include density, proportion occurrence, total abundance, size structure, partial mortality, prevalence of coral condition, such as disease and bleaching, and generic and species richness. Coral community metrics include relative abundance (percent cover), frequency of occurrence, and taxonomic composition.

Methodology

Description

Sampling Design

Coral abundance metrics are typically heterogeneous and vary in space according to environmental covariates, such as depth, topographic complexity, and patchiness of reef habitats (Smith et al. 2011; Swanson 2011). To account for such variation, a stratified random sampling design (StRS) was applied to more effectively and efficiently sample coral populations across defined strata (Cochran 1977; Swanson et al. 2018).

The stratification scheme for these surveys incorporates (1) three depth categories (shallow: 0 to 6 m; mid-depth: >6 to 18 m; and deep: >18 to 30 m); (2) regional sub-island sectors; (3) reef zone components, including back reef, lagoon, and fore reef. This scheme creates a survey domain that encompasses the majority of the mapped area of reef and hard bottom habitats from 0 to 30 m and provides a mechanism in which to allocate random samples across strata based on the stratum's proportional area and the variance structure of the population within the stratum.

Digital spatial databases of benthic habitats, reef zones, bathymetry, and marine reserve boundaries are integrated within a geographical information system (GIS) framework to facilitate the spatial delineation of the sampling survey domain, strata, and transects. A shapefile containing individual grid cells of size 50 m × 50 m in area are overlaid onto the survey domain to control for spatial variation in population parameters at scales smaller than the grid cell minimum mapping unit (2,500 m²) (Cochran 1977). In contrast to 2017, in 2018, a single stage sampling scheme was implemented, which designates primary sample units (referred to sites) as grid cells containing > 10% hard-bottom reef habitats. Within each grid cell, a fixed survey area of 10 m² or less is defined by a diver visual belt transect conducted on a random point that is generated within each grid (Smith et al. 2011).

From 2013 to 2017, survey effort was determined based on the number of days spent at each island and then allocated mainly by strata area and variance of target species. In 2018, effort was determined first by the number of days spent at each island and then by strata area and variance of target species at the island level. Targeted coral genera for the Pacific Remote Islands Marine National Monument included *Acropora* sp, *Montipora* sp, *Pavona* sp, *Pocillopora* sp, and *Porites* sp., while the targeted genera for American Samoa were *Acropora* sp, *Galaxea* sp, *Montipora* sp, *Pocillopora* sp, and *Porites* sp.

Benthic survey components

Surveys at each site are conducted within one, 10-meter belt transect (Figure 1) and include the following suite of observations:

- Adult coral colony (≥ 5 cm) abundance, size, partial mortality, and disease/condition
- Crustose coralline (CCA) disease
- Anthozoan presence
- Juvenile coral colony (< 5 cm) abundance and size
- Benthic cover



Figure 1. Diagram of a diver conducting a belt transect survey at an REA site.

Adult coral colonies

Adult coral colonies (≥ 5 cm) are surveyed within four (1.0×2.5 m) segments at 5 m increments along a single 18 m transect in the following manner: 0–2.5 m (segment 0); 5.0–7.5 m (segment 5); 10–12.5 m (segment 10); and 15–17.5 m (segment 15). The combined survey area of the segments is 10 m^2 per site. All colonies whose center falls within 0.5 m on either side of each transect line within each segment are identified to lowest taxonomic level possible (genus or species), measured for size (maximum diameter to nearest cm), morphology noted, and assessed for partial mortality and condition.

Partial mortality is estimated as percent of the colony in terms of old dead and recent dead, and the cause of recent mortality (or recent tissue loss) is identified when evident. Colony condition including disease (i.e., all lesions other than recent tissue loss) and bleaching is also noted along with the extent (percent of colony affected) and level of severity (on a scale from mid to acute for bleaching). The lowest taxonomic level for coral taxa is genus, except for a select number of species that can be consistently identified to species by all divers conducting the surveys. The number of species may change for each survey year depending on the experience and training of the benthic divers conducting the surveys.

Crustose coralline algae (CCA) disease

Within the same four segments per transect as the adult coral surveys, crustose coralline algae (CCA) diseases, occurrence, and lesion size (max. diameter) are noted.

Anthozoan (other cnidarians) presence

The presence/absence of other Anthozoans (other cnidarians including Alcyonareans, Zoantharians, coralliomorphs and Antipatharians) are noted within the four surveyed transect segments.

Juvenile coral colonies

Juvenile coral colonies (< 5 cm) are surveyed within three (1.0 × 1.0 m) segments along the same 18 m transect: 0–1.0 m (segment 0); 5.0–6.0 m (segment 5); and 10.0–11.0 m (segment 10). The combined survey area of the segments is 3 m² per site. Juvenile colonies are distinguished in the field by a distinct tissue and skeletal boundary (not a fragment or remnant of larger colony). The size of each juvenile colony larger than 0.5 cm is measured by recording the maximum diameter to the nearest 0.5 mm. Similar to adult corals, juvenile corals are identified to genus given that in most cases, juvenile corals will likely be too small to positively identify to the species level.

Benthic cover

Estimates of benthic cover are generated from benthic images (hereafter photoquadrats), which are photographed along the 18 m transect per site. Benthic substrate photos are collected at one meter intervals along each side of the transect line (15 photos on each side, starting at the 1 m mark) for a total of 30 photoquadrats per site. The benthic photoquadrat imagery is analyzed using the web-based annotation tool CoralNet (Beijbom et al. 2015) by placing 10 random points per photo, and the benthic elements falling directly underneath each point are identified to three functional group levels: Tier 1 (e.g., hard coral, soft coral, macroalgae, turf algae), Tier 2 (hard coral by morphology: massive, branching, foliose, encrusting, etc.), and Tier 3 (e.g., hard coral by genus and morphology; macroalgae by genus and grouped genera). The standard operating procedures for the analysis of benthic substrate imagery can be accessed at Lozada-Misa et al. (2017); an updated version will be forthcoming.

Field Implementation

Equipment

Survey dives are conducted from small (6–9 m) boats launched from the support ship to the pre-selected, random stratified dive sites. Prior to launching each morning, the following equipment is packed and transported onto each small boat (Table 1).

Table 1. Gear required for benthic survey operations.

Topside	Per Buddy Pair	Per Individual Diver
GPS unit loaded with pre-selected, random stratified sites	One 30-m transect tape	Benthic survey data sheet on underwater slate
REA site list	Surface marker buoy with 50-m dive reel	Region specific field “cheat sheet” for coral taxonomic identification
REA site map		Pencils
Dive and Navigation Information datasheet		Rulers for adult and juvenile coral colony size measurements
Randomized list of depths per depth strata		0.5-m stick (PVC stick marked at 5-cm intervals)
		1-m monopod (PVC collapsible stick for photoquadrat surveys)
		Underwater digital camera

Site Selection and Assessment

Prior to the start of each mission, random survey locations (REA sites) are generated in GIS, and field survey maps are created. These maps provide a list of primary and secondary sites for each day of field operations. Secondary (alternate) sites serve as backup sites in the event that primary sites turn out to be inaccessible or unsuitable (e.g., because of mapping errors in depth or substrate type). Waypoints are randomly placed within each REA site (50 m × 50 m grid), named with a site ID (a standard 3-letter island code and a 3 or 4 number site code), and uploaded into the benthic team GPS instruments.

Upon arrival at the REA site, a small boat depth sounder is used to record the depth of the random point within the site. To avoid biasing the placement of the transect tape within the site if a depth contour exists, divers should use depth sounder’s depth as their survey starting point. If possible, divers should inspect the site from the surface by snorkeling to determine whether the substrate at the survey location is reef habitat. If it is not possible to inspect the site with these methods, divers should attempt to drop directly from the waypoint and descend to the predetermined depth. **The area to be surveyed must contain a minimum of 25% hard bottom habitat** (Figure 2). Surveys should not be conducted in sand habitats. However, where substrate is hard bottom with a light dusting cover of sand, it is still acceptable to survey in that habitat. If the benthic habitat is sand, sediment, or does not contain a minimum of 25% hard bottom habitat, the divers should swim in one direction for one minute to try to find suitable habitat within the depth range of target stratum. If no suitable reef habitat is found (Figure 3), the site should be aborted, and the team should relocate to the next site or alternate site. Divers should not swim toward a site that “looks” good (i.e., more coral). The GPS coordinates for the unsuitable site should be recorded on the Dive and Navigation Information Sheet (Figure 4) and listed as unsurveyable as sand, *Halimeda* flat, too deep, or other.

If the site depth needs to be adjusted, for example, because the original GPS coordinates position the site in the wrong depth stratum, divers should refer to the list of random depths for each depth strata rather than choosing our own depth. Topside, the new site coordinates should be recorded on the GPS unit while noting the original coordinates and the depth.

Although the divers drop on the random waypoints for each site, the location of the actual survey may shift due incorrect depth (as aforementioned) or sea conditions. **Therefore, it is critical to record the location of the actual survey with the handheld GPS unit. Divers should work with the small boat coxswain to record the site waypoints while the divers are conducting the survey. The GPS coordinates for the site location should be recorded on the Dive and Navigation Information Sheet (Figure 4).**



Figure 2. Examples of suitable habitat. NOAA photos.

- Deployment of transects
- Site characterization
- Minimum and maximum depths for each transect area (recorded in feet)
- General site photographs
- Ecological surveys: Adult corals, CCA disease, Alcyonarian presence, and juvenile corals
- Photoquadrats for benthic cover estimates

The separation of tasks among the dive team may vary, but all members should work cooperatively to survey each site as efficiently and safely as possible.

Transect deployment

If the survey area encompasses a steep incline ($\sim >45^\circ$), then the 18 m transect line should be deployed along the depth contour; otherwise, the transect line should be run from offshore to inshore.

Recording site and survey data

Benthic survey and site characterization data are recorded underwater on the benthic survey data sheet (Figure 5). At the top of the data sheet, there are specific sections to record the diver names or initials (**A**), the date (**B**), the island and habitat types (**C**), site notes (**D**), site name (**E**), the minimum and maximum depth (ft) around transect 1 (**F**) and transect 2 (**G**). There is additional space for comments at the bottom of the data sheet (**H**).

BENTHIC CORAL DATA SHEET

Location/Habitat: _____ Site Notes: _____ Observer: _____ Date: _____

Site: _____ Depth T1 (min/max): _____ Depth T2 (min/max): _____

Col	T	Seg	Taxon	Morph	L (cm)	W (cm)	%Dead	%Recent	RD cause	Condition	Ex	Sv	Comment
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
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40													

Comments: _____

Figure 5. Sample benthic survey data sheet used underwater to record coral colony survey and site characterization data.

Site photos

The primary photographer should take a minimum of four landscape-oriented photos of the site (Figure 6). These photos should be taken from within the general transect area at evenly spaced intervals as the diver rotates 360°. More photos or video may be taken as needed to provide a permanent record of the overall characteristics or unique features of the site.



Figure 6. Examples of site photos taken within a transect area. *NOAA photos.*

Habitat types

Reef habitat type should provide a description of the general survey area (50 × 50 m grid cell, 2500 m²). This is characterized by selecting the most appropriate choice that describes the habitat encompassed by the general survey area from the following ten categories (Table 2) that have been modified from Kendall and Poti (2011).

Because of the great variety of reef habitats comprising ecosystems around the many Pacific islands surveyed by the ESD, a survey area may not fall neatly into one of these categories. The category with a definition that fits the majority of the habitat should be selected. At the surface, following the dive, the divers should discuss questionable habitat types with their buddies and come to a consensus. The agreed-upon habitat type will be entered in the benthic survey data sheet (Figure 5), as well as the Dive and Navigation Information Sheet along with the site min and max depth based on the observed transect depths (Figure 4).

Table 2. Reef habitat types and codes.

Habitat Type	Code
Aggregate reef	AGR
Aggregate patch reef	APR
Aggregate patch reefs	APS
Pavement	PAV
Pavement with patch reefs	PPR
Pavement with sand channels	PSC
Boulder/rock	ROB
Reef rubble	RRB
Spur and groove	SAG
Sand with scattered coral and rock*	SCR

**This habitat is generally not surveyed*

1. Aggregate reef (AGR): Indicates hard-bottom substrate with corals; also referred to as continuous or consolidated reef (Figure 7). This habitat type may have high relief but lacks the sand or pavement channels of spur and groove habitat. Most reefs that do not obviously fall in other types should be recorded as aggregate reef.

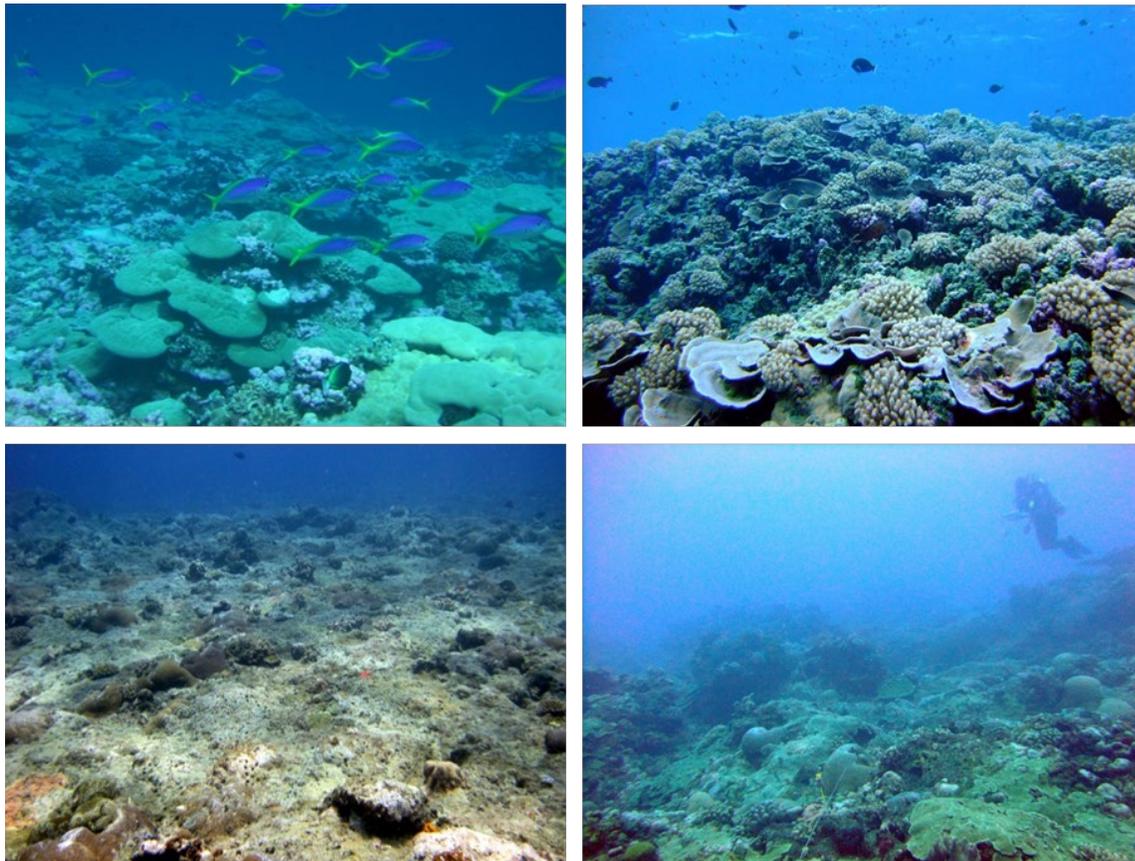


Figure 7. Examples of aggregate reef. NOAA photos.

2. Aggregate patch reef (APR): These are 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 (Figure 8). They are often characterized by a circular or oblong shape with vertical relief of one meter or more in relation to the surrounding seafloor. This category of reef is larger or equal in size to the general survey area of 50×50 m. This habitat type is most commonly noted in lagoon (e.g., Rose Atoll) or back reef areas (e.g., in northern Pearl and Hermes Atoll and Midway Atoll).



Figure 8. Aerial imagery of an aggregate patch reef in Kāneʻohe Bay, Oʻahu, Hawaiʻi.
Photo by J. Levy, University of Hawaiʻi Applied Research Laboratory.

3. Aggregate patch reefs (APS): This category is for patch reefs that have the same defining characteristics of an Aggregate (individual) Patch Reef, but are smaller in size. Therefore, multiple patch reefs are found within the 50 × 50 m survey area (Figure 9).



Figure 9. Examples of aggregate patch reefs habitat. *NOAA photos.*

4. Pavement (PAV): These are 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 (Figure 10).



Figure 10. Example of pavement habitat. *Photo by D. White, Hawai`i Department of Land and Natural Resources.*

5. Pavement with patch reefs (PPR): This category is for areas of pavement with occasional patch reef formations that make up less than 10% of the general area (Figure 11).

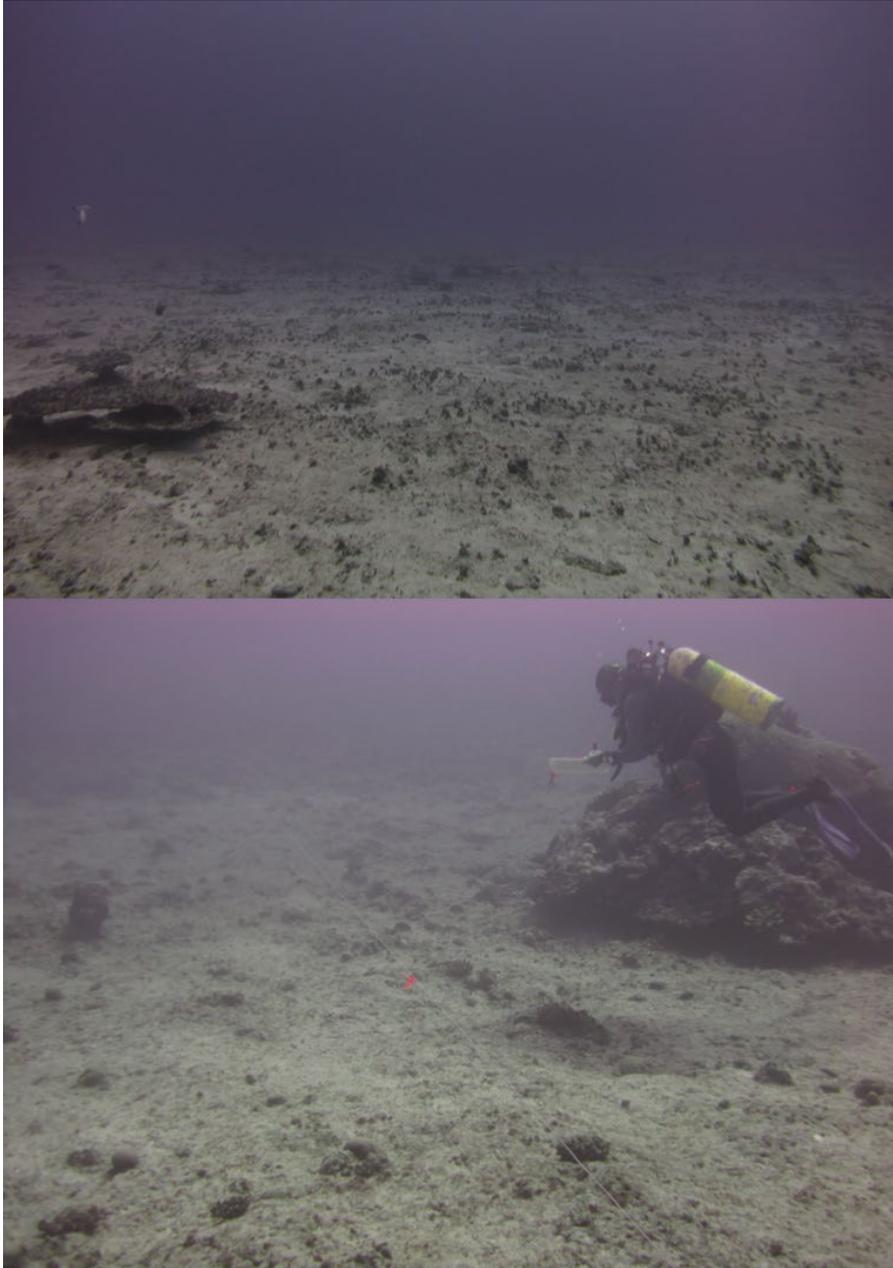


Figure 11. Examples of pavement with patch reefs habitat. *NOAA photos.*

6. Pavement with sand channels (PSC): These are habitats of pavement with alternating sand/surge channel formations that are perpendicular to the shore, bank, or shelf (Figure 12). 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 such as the bank/shelf zone.



Figure 12. Examples of pavement with sand channels habitat. *NOAA photos.*

7. Rock/Boulder (ROB): Large, irregularly shaped carbonate blocks or rock boulders often extending offshore from the island bedrock or headlands are referred to as ROB. This habitat type 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 0.25–3 m, with very little benthic cover present (Figure 13).

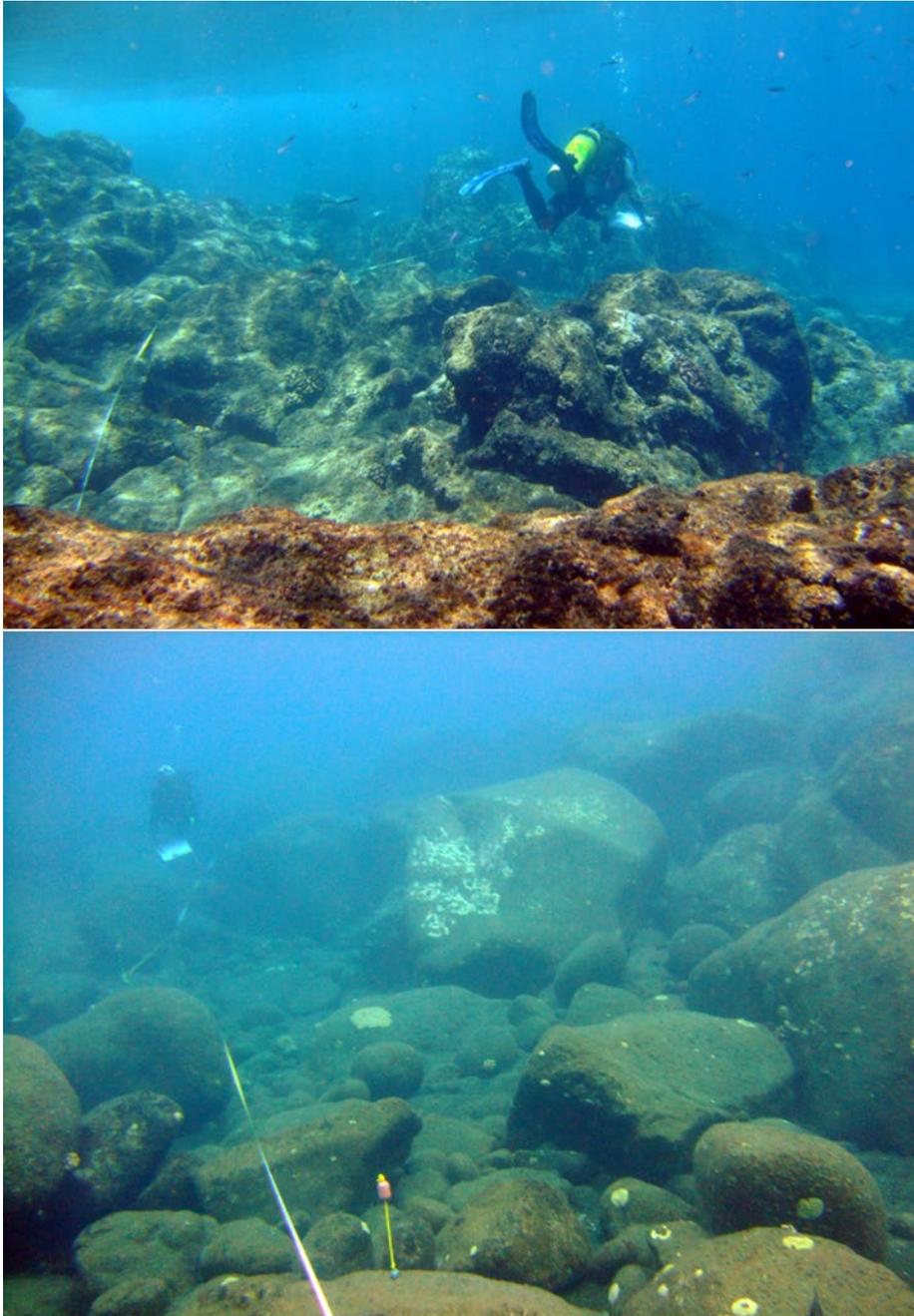


Figure 13. Examples of rock/boulder habitat. *NOAA photos.*

8. Reef rubble (RRB): These are areas carpeted by unconsolidated, small (< 10 cm) fragments of coral skeletons or reef rock often colonized with filamentous or other macroalgae (Figure 14). This habitat often occurs landward of well-developed reef formations in reef crest or back reef zones.



Figure 14. Examples of rubble habitat. *NOAA photos.*

9. Spur and groove (SAG): Refers to habitats with alternating sand and coral formations that are oriented roughly perpendicular to the shore, bank, or shelf (Figure 15). 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.

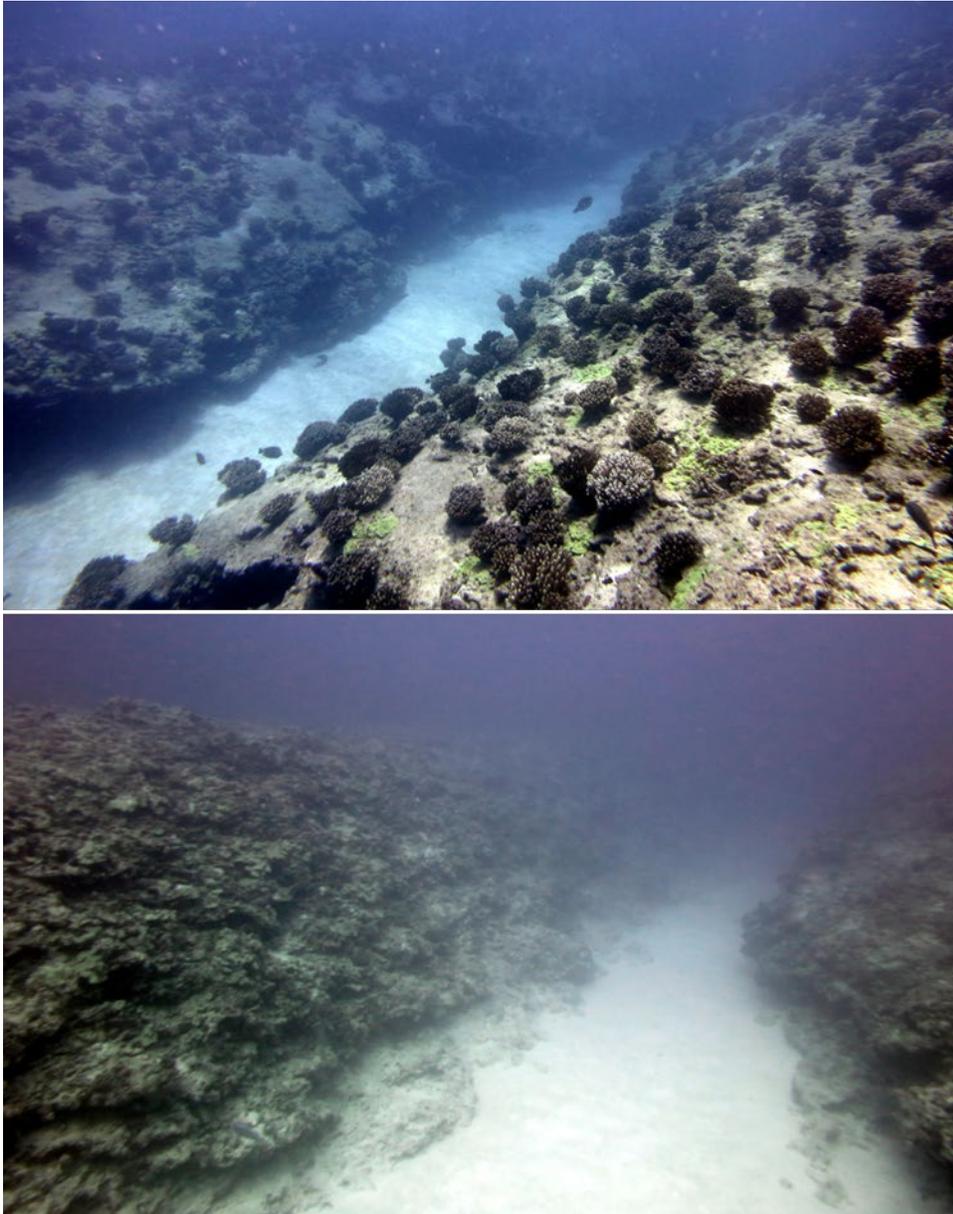


Figure 15. Examples of spur-and-groove habitat. *NOAA photos.*

10. Sand with scattered coral and rock (SCR): These are primarily habitats of sand or seagrass bottom with scattered rocks or small, isolated coral heads that make up less than 10% of the general area (Figure 16). **These habitats are generally not surveyed**, but this habitat is recorded on the benthic data sheet. This habitat will only be surveyed if the sand is actually only a thin layer coating hard substrate.



Figure 16. Examples of Sand with Scattered Coral and Rock habitat. *NOAA photos.*

Adult coral surveys

Surveys of adult coral colonies are conducted within four 1.0 m wide × 2.5 m long segments centered along the 18-m transect (Figure 17), where each segment is numbered as follows: **Segment 0** = 0–2.5 m; **Segment 5** = 5.0–7.5 m; **Segment 10** = 10–12.5 m; **Segment 15** = 15–17.5 m.

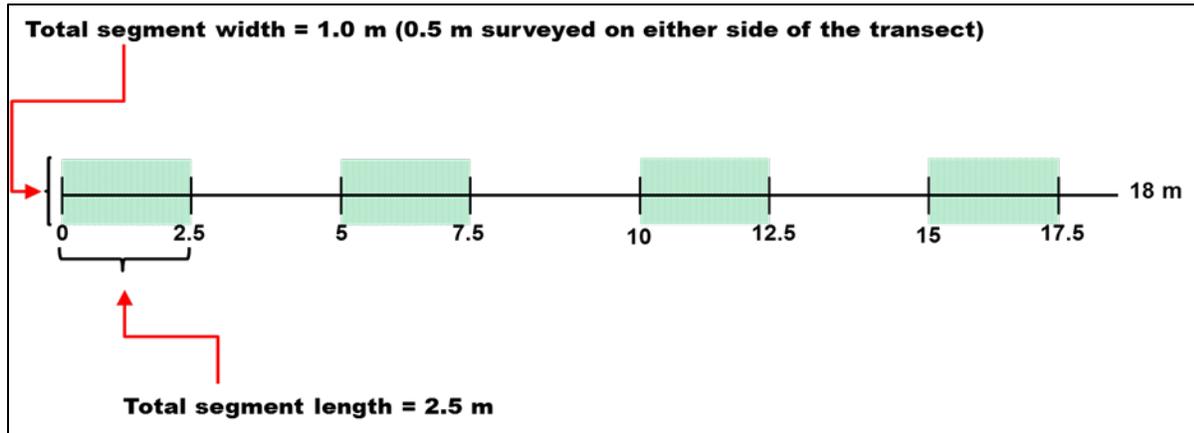


Figure 17. Example of the four survey segments on an 18 m transect.

Divers conducting the surveys should alternate segments to maintain a safe distance from their dive buddy (e.g., diver 1 completes Segments 0 and 10 while diver 2 completes Segments 5 and 15). If a diver cannot completely survey the entire segment area in the time allotted (i.e., due to limited bottom time), the dimensions of the partial segment area survey will need to be recorded along with the coral colonies present.

Only adult coral colonies (≥ 5 cm) whose center is found within the boundaries of the segment are included in the survey (Figure 18). However, large colonies whose center falls outside the segment but occupy $>75\%$ of the total segment, are also counted. All Scleractian coral species are included in these surveys, as well as the hydrozoan “fire corals” (*Millepora* spp.) and the octocoral “blue coral” *Heliopora coerulea*.

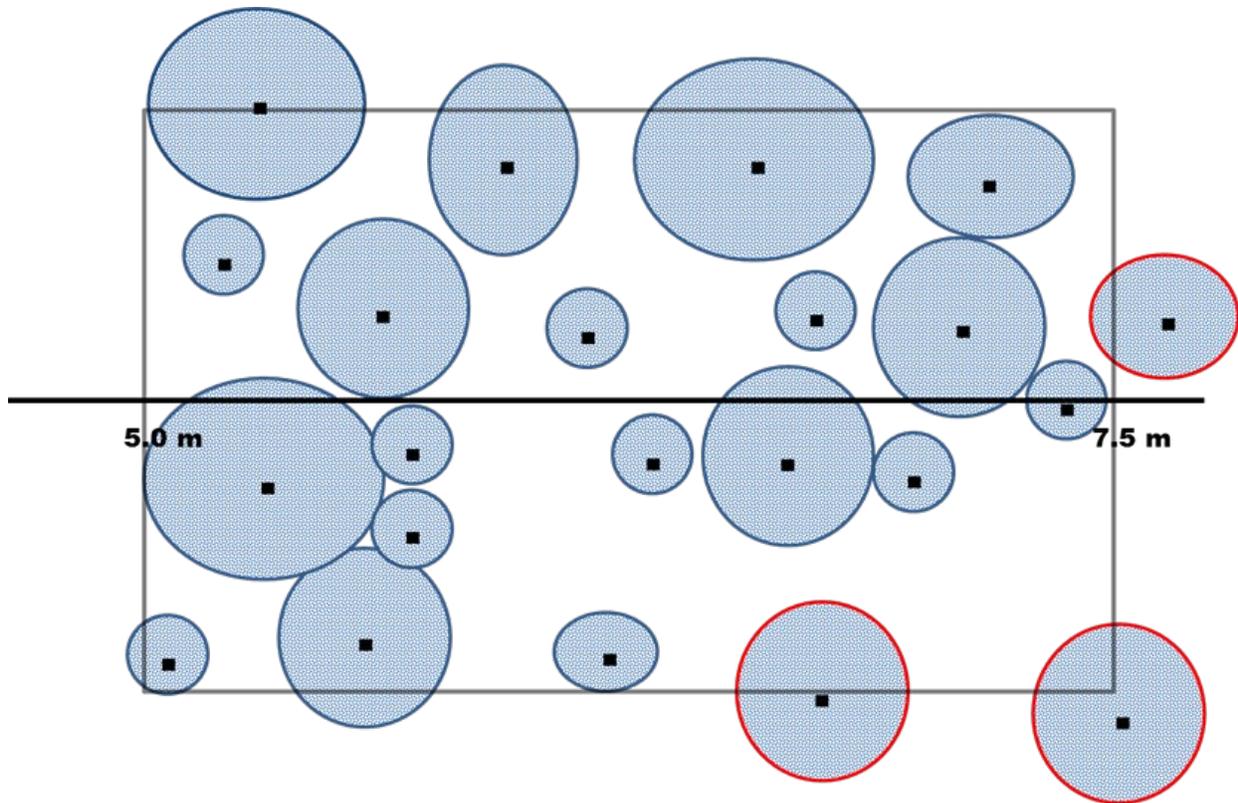


Figure 18. Diagram to show an example of the center rule used to survey coral colonies. Modified from Zvuloni et al. (2008).

Individual colony determination

Due to partial mortality, identification of an individual colony can be difficult. Considerations used to determine an individual colony include:

- 1) Are there pieces of live tissue on a common skeletal structure?
- 2) Are the pieces of tissue similar in color and polyp form?
- 3) Are the pieces of live tissue more than 10 cm apart?

If live tissue pieces are on a common skeletal structure, similar in color and polyp form, yet more than 10 cm apart, they are still considered as the same colony (Figure 19). If the live tissue pieces are not on a common skeletal structure and more than 10 cm apart, but similar in color and polyp form, they are considered different colonies. If the pieces of tissue are not similar in color and polyp form, they are considered different colonies, regardless of skeletal structure and the distance between pieces.

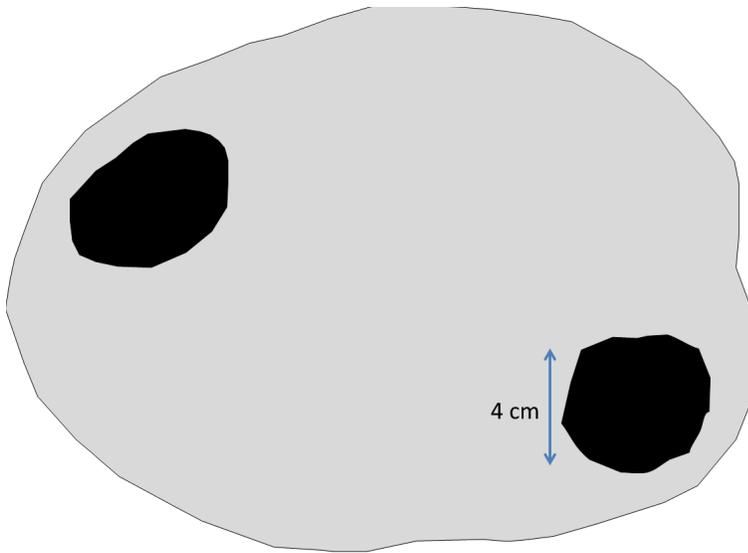


Figure 19. Schematic diagram of a coral colony with live tissue pieces represented by black areas and the previous colony margin represented by the grey area. *Special note:* If a colony is a remnant of a larger colony and less than 5 cm but cannot be defined as a juvenile, it must be included in the adult survey. These colonies are likely non-reproductive but have been shown to have similar growth rates as the intact adult tissue. By distinguishing juveniles from small colonies resulting from fission, estimates of juvenile abundance are improved.

Morphology

To model the reproductive potential of coral populations, morphological (MORPH on datasheet) identification is critical in converting empirical length measurements from the field surveys to colony surface area. This category includes fifteen simplified versions of colony growth morphologies and geometric shapes (Table 3). Morphologies may not always fit neatly into one of these fifteen categories; however, the one which best describes the general shape of the colony should be recorded.

Table 3. Morphology categories identified during field surveys of adult coral colonies.

Morphology	Code	Description
Encrusting (flat)	EF	Adheres to a flat surface; “pancake glued to the bottom”
Encrusting (mounding)	EM	Adheres to a (e.g., ledge); “frosting on a cake”; this category also includes colonies that are encrusting inverted
Encrusting (columnar)	EC	Adheres to a relatively flat surface and also has columns; encrusting or spread out base or portion of the colony with “branches, knobs, columns or chimneys” (e.g., <i>Montipora capitata</i>)
Mounding	MD	Solid and similar in shape in all dimensions; Ellipsoid – small or large, sometimes spherical
Plating	PL	Forms simple plate extending outwards from the benthic substrate, akin to a shingle on a roof—note that this morphology denotes single, not multiple plates
Bifacial Plates	BP	Vertically oriented plates or thin “blades”
Foliose	FO	Plates that form whorls – usually multiple plates, “a head of lettuce”
Laminar	LM	Multiple plates on a larger structure; “shingles on a mound”
Laminar-columnar	LC	Combination of laminar and columnar morphologies, multiple plates on a larger structure with columns protruding from the top; “candles on a tiered birthday cake”; common for <i>Porites rus</i> and <i>Montipora capitata</i>
Branching	BR	Branches present; “fingers”
Knobby	KN	Stubby branches; “knuckles”
Columnar	CO	Forms columns of stumps that do not share a common base like branching corals generally do. Columns are considered to be structure larger in length than width.
Table	TB	Forms a table with one central leg attached to the substratum, common for <i>Acropora</i> spp. such as <i>A. cytherea</i>
Mounding lobate	ML	Mounding, vertically oriented lobes or “pork chops”; common for <i>Pavona duerdeni</i>
Disc (free living)	FR	Not attached to any substrate (only in the juvenile stage; e.g., <i>Fungia</i> sp.) including species with forked axial furrows becoming Y, T, or X shaped – <i>Polyphyllia</i> and <i>Herpolitha</i> .

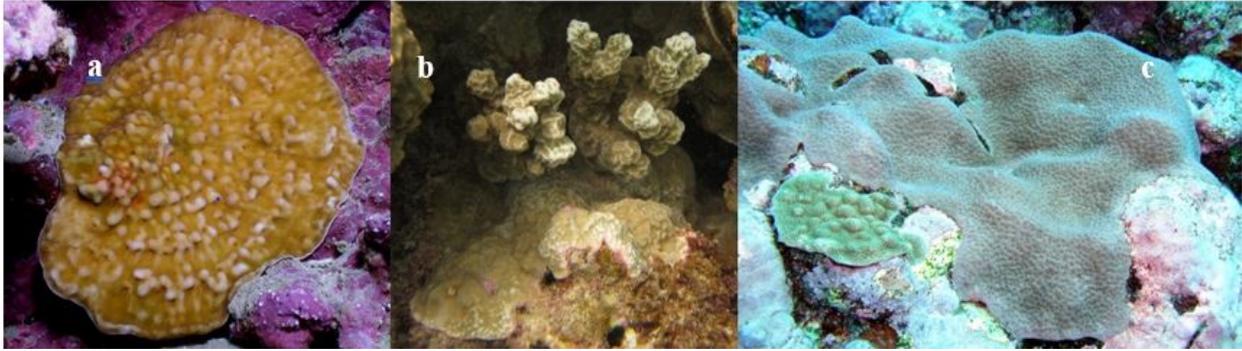


Figure 20. Example of encrusting coral morphologies: (a) flat; (b) columnar; (c) mounding/massive. *NOAA photos.*



Figure 21. Example of (a) plating, (b) bifacial plating, and (c) foliose coral morphologies. *Guamreeflife.com and NOAA photos.*



Figure 22. Example of (a) laminar, (b) laminar-columnar, and (c) table coral morphologies. *Guamreeflife.com and NOAA photos.*

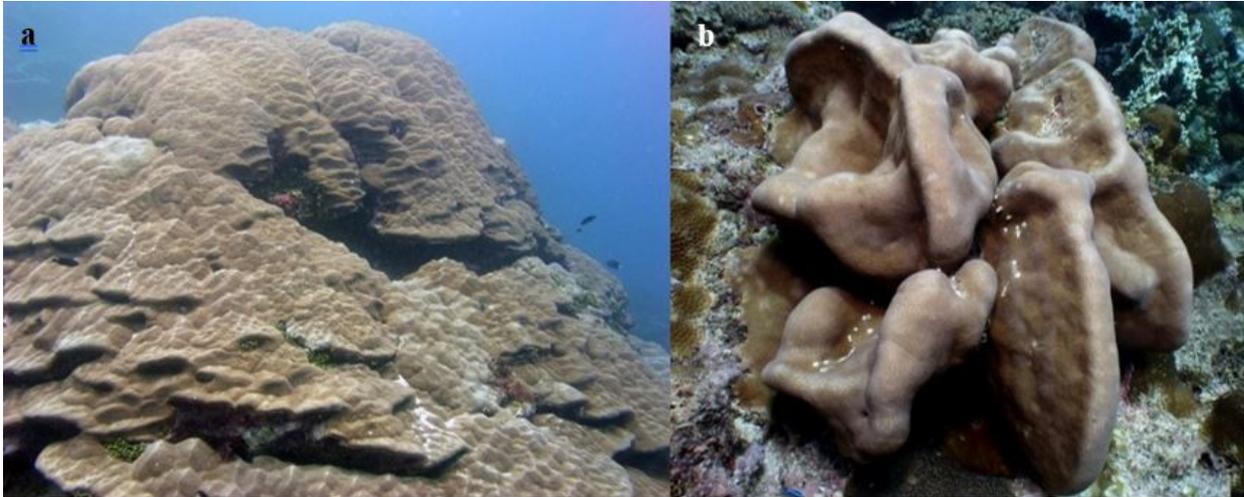


Figure 23. Example of (a) massive/mounding and (b) mounding-lobate coral morphologies. *NOAA photos.*

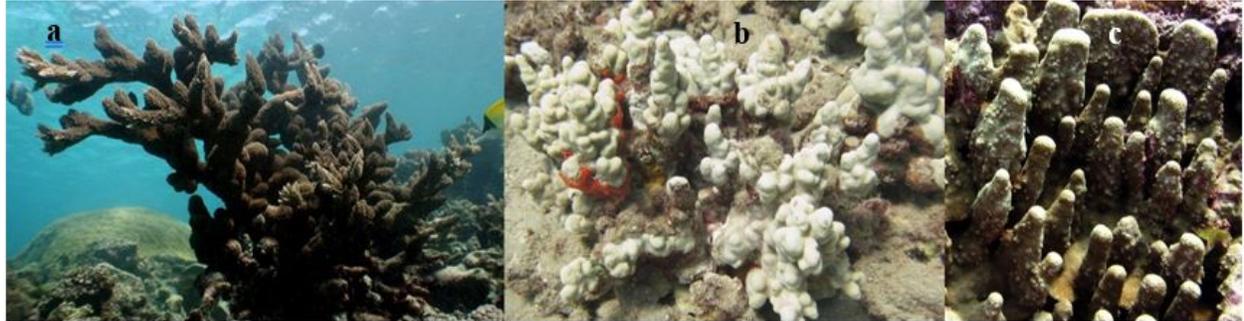


Figure 24. Example of (a) branching, (b) knobby, and (c) columnar coral morphologies. *NOAA photos.*



Figure 25. Example of a free living/disc coral morphology. *NOAA photos.*

Measurement of colony size

The length of an entire adult colony (including partial mortality) is measured across the maximum diameter to the nearest centimeter (1cm) (Figure 26). The diameter must be measured with respect to colony growth orientation rather than from a planar perspective. For juveniles only, the width of the colony is taken as the maximum distance perpendicular to the length of the colony.

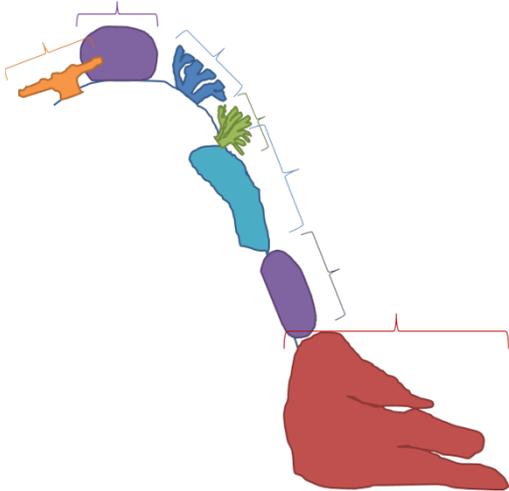


Figure 26. Schematic of maximum coral diameter measured depending on the orientation of various coral morphologies.

Partial mortality

Partial mortality is classified as either ‘old dead’ or ‘recent dead’ and estimated on each colony as a percent of colony surface area using the following criteria: to the nearest 1% for mortality ranging > 0–10% and >90–100%; and to the nearest 5% for mortality ranging >10–90%. If a colony is entirely dead (in any combination of old dead and recent dead), **do not measure the colony**.

Old partial mortality (‘% Dead’ on datasheet; Figure 5) is defined as the non-living portion of a colony where the corallite structures are either gone or covered over by fouling organisms that are not easily removed. This portion of the colony is where the live tissue is presumed to have died within the last few months to years or longer. The cause of old dead mortality is rarely known, and therefore not recorded.

Recent dead (‘% Recent’ on datasheet; Figure 5) is defined as the non-living portion of a colony in which the corallite structures are still intact (unless freshly bitten by a fish or abraded) and the exposed skeleton is either stark white or has only a very thin layer of sediment, biofilm (i.e., bacteria), diatoms, or tiny turf algae.

The cause of recent dead (‘RD Cause’ on datasheet; Figure 5) is recorded, even if it must be recorded as unknown. There are 6 general causes of recent mortality: disease, predation, overgrowth, sediment, physical damage, and unknown (Table 4). Within the category of disease,

predation, and overgrowth there are a few specific causes of recent dead that should be identified if they can be scored with confidence (if not, simply denote one of the 5 general categories)

When there are multiple causes of recent dead, be sure to attribute a % recent mortality to *each* cause.

Table 4. General (bold) and specific categories of recent dead partial mortality.

Recent Dead Cause	Code
Disease-general	DZGN
Acute tissue loss - white syndrome	WSY
Sub-acute tissue loss	TLS
<i>Porites</i> ulcerative white spot	PUS
Banded fungal Infection	BFI
Brown band disease	BRD
Black band disease	BBD
Ciliate infection	CIL
Predation-general	PRED
Crown of thorns predation	COTS
Fish predation	FISH
Gastropod predation	GAST
Overgrowth-general	OVRG
Macroalgae	MACA
Octocoral	OCTO
Zoanthid	ZOAN
Tunicate	TUNI
Coralimorph	CORM
Sediment -general	SEDI
Physical damage-general	DAMG
Unknown	UNKN

Recent mortality causes: [Disease \(DZGN\)](#)

These are diseases that cause tissue loss lesions, leaving behind a recently dead area (small or large) of exposed coral skeleton. Six specific diseases should be recorded if observed including: acute tissue loss or white syndrome (WSY), sub-acute tissue loss (TLS), *Porites* ulcerative white spot (PUS), banded fungal infection (BFI), brown band disease (BRD), and black band disease (BBD). If recent dead percent is recorded and disease is noted but the diver cannot define the type as one of these specific six diseases of interest, then the disease general code (DZGN) should be recorded.

Acute tissue loss or white syndrome (WSY): Acute tissue loss or white syndrome is a collective term to describe lesions characterized by the rapid loss of tissue, leaving behind a sharp, clean band, where tissue is completely removed from the skeleton (Figure 27). A progression of filamentous and turf algae often covers the exposed skeleton, illustrated by a color gradient from bare skeleton to brown as the fouling community develops. The disease generally progresses rapidly, leaving behind a narrow to wide band of recently denuded coral skeleton (the entire colony may be almost completely stark white with only a little tissue remaining). Our assessments have recorded white syndrome on at least 6 Pacific genera representing 4 scleractinian families, with species of *Acropora* and *Montipora* being the most common hosts. In the Northwestern Hawaiian Islands, this disease is lethal to table acroporids.



Figure 27. Example of acute tissue loss or white syndrome. NOAA photos.

Sub-acute tissue loss (TLS): Sub-acute tissue loss is a collective term to describe lesions resulting in slow but progressive loss of tissue (Figure 28). It is distinguished from white syndrome by the narrow width of the zone of recently exposed skeleton. Bare white skeleton is often not present, but instead there is a very thin layer of sediment, biofilm (i.e., bacteria), diatoms, microalgae, or tiny turf algae. Look for progression in age of filamentous turf algae that has settled on dead areas of colony. The lesion margin is often mucousy or has sloughing tissue. This is easily confused with gastropod predation, so take photos liberally.

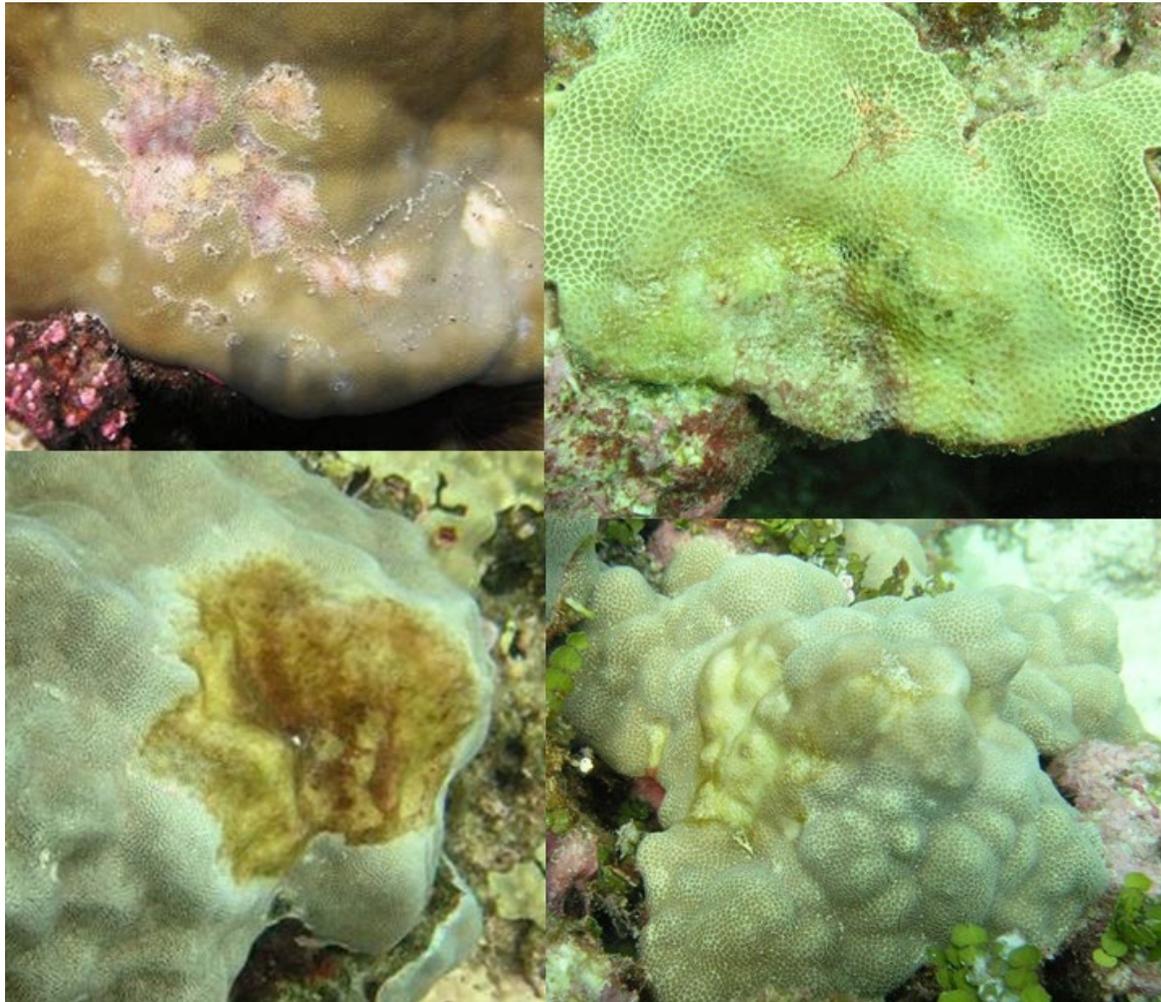


Figure 28. Examples of subacute tissue loss (TLS). NOAA photos.

Porites ulcerative white spot (PUS): These multifocal patterns of tissue loss expose spots of bare white skeleton (Figure 29). Lesions are typically small (< 1cm diameter) and regularly ovoid. These lesions may start as bleached spots. A colony may contain both bleached lesions and lesions devoid of tissue. Abundance: rare.



Figure 29. Examples of *Porites* ulcerative white spot (PUS)

Banded fungal infection (BFI): Diseased colonies exhibit a distinct yellow to bright green mat about 1–3 cm wide on the coral tissue (Figure 30). A progression of filamentous and turf algae generally appears on the exposed skeleton as the tissue is lost. The unaffected coral tissue appears normal in color and morphology.



Figure 30. Examples of banded fungal infection (BFI). NOAA photos.

Brown band disease (BRD): Brown band disease is characterized by bands composed of ciliates, varying from light to dark brown with ciliate density (Figure 31). A narrow white band may be present between live coral tissue and brown band. The rate of progression is rapid (20–100 mm/day).

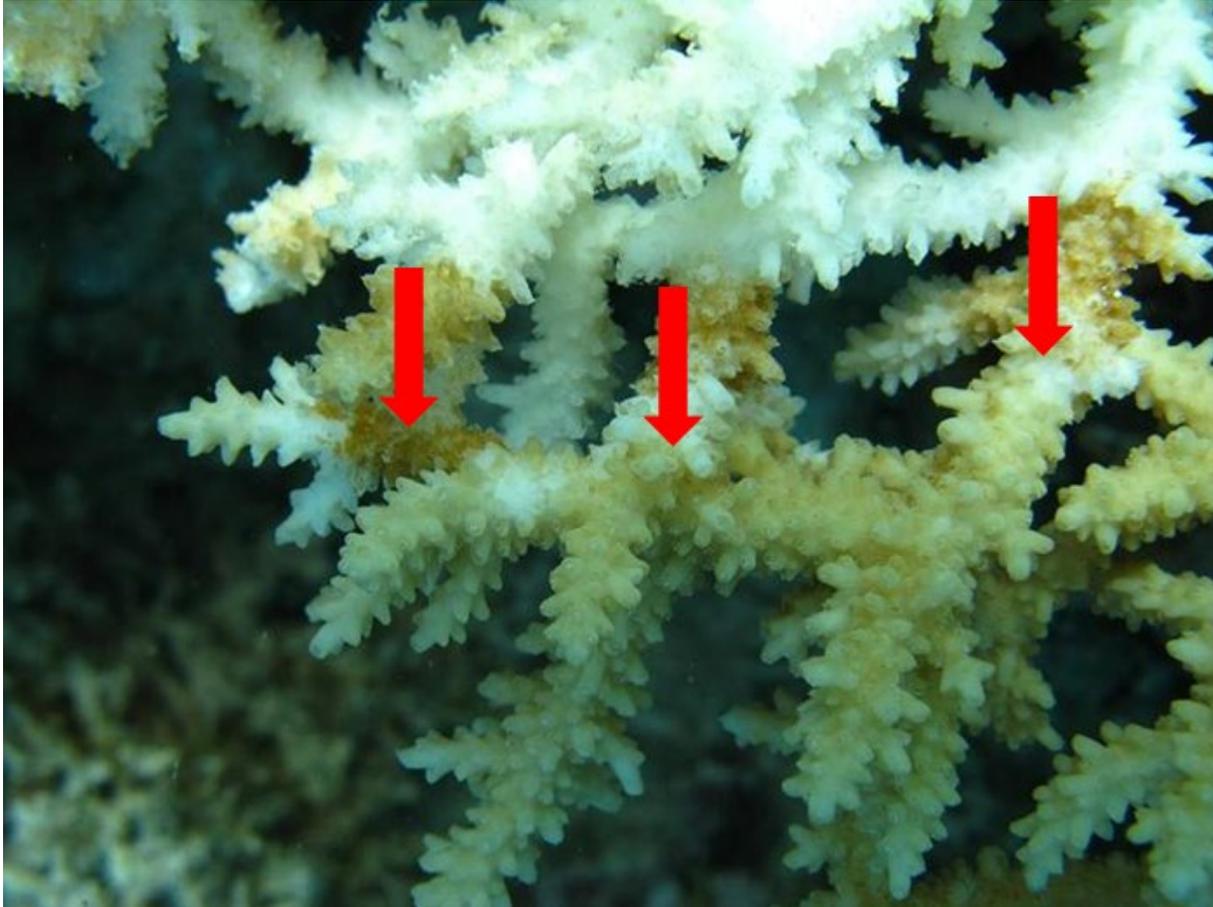


Figure 31. Example of brown band disease (BRD). NOAA photos.

Black band disease (BBD): This condition is characterized by a distinct black to grey mat, ~0.5–4 cm wide, on the living coral tissue that leaves behind the bare white skeleton (Figure 32). The band color can vary from black to gray or reddish-brown. The unaffected coral tissue appears normal in color and morphology. The skeleton distant from the tissue front often turns progressively brown as it becomes colonized by a fouling community. Lesions are variable in size and shape. Distribution and abundance: rare across ESD’s study region, although a major outbreak was reported in Kauai (Main Hawaiian Islands) in 2013. Can be found across the globe and has been sighted in American Samoa and other areas in the main Hawaiian Islands.



Figure 32. Examples of black band disease (BBD). NOAA photos

Ciliate Infection (CIL): Lesions are variable in shape and size and characterized by a diffuse gray to black band or patch about ~0.5 to 3 cm wide, separating the healthy tissue from the exposed coral skeleton. The unaffected coral tissue appears normal in color and morphology; lesions have a speckled appearance that is caused by the presence of ciliates lodged in the coral skeleton. Generally, filamentous and turf algae appear on the exposed skeleton as the tissue is lost. Distribution and abundance: rare, with sightings registered around the main Hawaiian Islands (Maui and Hawaii), affecting preferentially *Montipora capitata* and *Pocillopora meandrina*.



Figure 33. Examples of ciliate infection (CIL). NOAA photos.

Recent mortality causes: Predation (PRED)

Crown of thorns sea star (COTS): The lesions caused by crown of thorn sea star predation are evident by the conspicuously shaped scars, forming focal-to-diffuse tissue loss lesions that expose the bare coral skeleton (Figure 34). Recent lesions are white and generally exhibit a discrete and scalloped border. The border may show visible strings of tissue and mucus when the scar is fresh. COTS are frequently present in the survey area.



Figure 34. Examples of crown of thorns sea star (COTS) predation NOAA photos.

Fish (FISH): Recent lesions caused by fish predation are predominantly inflicted by corallivorous fishes (parrotfish, pufferfish, and butterfly fish families) (Figure 35). Fish bites create very distinctive gouges or scrapes. These bite marks may also involve damage of coral skeleton. Do not record damselfish bites/chimney or “blenny kisses”.



Figure 35. Examples of fish (FISH) predation NOAA photos

Gastropod (GAST): Recent lesions caused by gastropod predation are focal, multifocal, or diffuse scars that expose the bare coral skeleton (Figure 36). Feeding scars have an irregular border. Shredded strings of tissue may be visible. Snails are often found on neighboring colonies if not immediately visible beside the feeding scars.



Figure 36. Examples of gastropod predation (GAST) NOAA photos

Recent mortality causes: Overgrowth (OVRG)

Live coral tissue can be overgrown by a variety of organisms. A zone of white exposed skeleton between the overgrowing organism and live coral tissue is generally present (Figure 37). Specific types of overgrowth include: macroalgae (MACA), octocoral (OCTO), zoanthid (ZOAN), tunicates (TUNI), and coralimorphs (CORM). The amount of overgrown coral (estimated by % recent dead) should only be measured as the small amount that is visible revealed underneath the overgrowing organism or peeled back to reveal the lesion (Figure 37).



Figure 37. Example of a recent dead lesion caused by overgrowth of *Palythoa* sp. The amount of colony affected is represented by the area outlined in green. NOAA photos.

Recent mortality causes: Sediment necrosis (general; SEDI)

Recent dead lesions caused by sedimentation are characterized by a diffuse area of tissue loss associated with fine sediment accumulating in hollows on coral surfaces, and on coral polyps and tissue. This visible sediment deposition, which is at times accompanied by mucus secretion and pigmentation response, is a key identifying characteristic of mortality due to sedimentation.

Recent mortality causes: Physical Damage (general; DAMG)

This category includes any recent dead caused by physical damage to the colony including abrasion, breakage, dislodgement, or toppling of the colony. Damage caused by boating and fishing gear (such as nets, chain, line, anchors, etc.) are also included here.

Recent mortality causes: Unknown (UNKN)

Recent dead lesions caused by unknown causes or by a cause not listed in Table 4 are recorded as unknown.

Condition

Colony condition ('Condition' on data sheet; Figure 5), includes instances of disease, bleaching, and physical damage (Table 5). Unlike recent dead, the coral tissue is still alive, and the polyps are visible. All condition codes require an assessment of extent ('Ex' on the datasheet) as % of colony affected; estimated to the nearest 1% for extent ranging > 0–10% and > 90–100%; and to the nearest 5% for extent ranging > 10–90%. Two conditions, bleaching (BLE) and patchy bleaching (BLP), also require assessment of severity. Severity values ('Sv' on data sheet) range from 1 to 5 (e.g., 1 = slight paling; 5 = stark white skeleton). The default code in the data entry program is NDZ, which is defined as no condition recorded.

Table 5. List of conditions that may be found on coral colonies.

CONDITION	Code
Algal infection	ALG
Endolithic fungal Infection	FUG
Skeletal growth anomalies	SGA
<i>Porites</i> trematodiasis	PTR
Barnacle infestation	BIN
Tube worm infestation	TIN
Pigmentation response	PRS
Discoloration (other than bleaching)	DIS
Bleaching (record severity)	BLE
Patchy bleaching (record severity)	BLP
Physical Damage	DAMG

Algal infection (ALG): An algal infection is the colonization and overgrowth of living coral tissue by various species of algae. With heavy overgrowth, underlying coral tissue usually dies, leaving bare skeleton (Figure 38). This condition is most often associated with an infiltration of filamentous red turf algae (Figure 38) and may cause a pigmentation response.



Figure 38. Example of algal infection (ALG). NOAA photos.

Endolithic fungal infection (FUG): An endolithic fungal infection is characterized by irregular, patchy, dark discoloration of coral live tissue (Figure 39). The discoloration can be identified by multifocal or diffuse areas of brown, reddish brown, or purple colored tissue discoloration. FUG is commonly observed on a variety of encrusting taxa including: *Montipora*, *Pavona*, *Porites*, *Leptastrea*, and *Cyphastrea*. Histologically, the upward migration of fungal hyphae into the thecal cavity is generally associated with disruption of the polyp body wall and sloughing of gastrodermis. Distribution and abundance: common but not abundant, with cases reported in the main Hawaiian Islands, Northwestern Hawaiian Islands, American Samoa, Guam, the CNMI, and Line Islands.

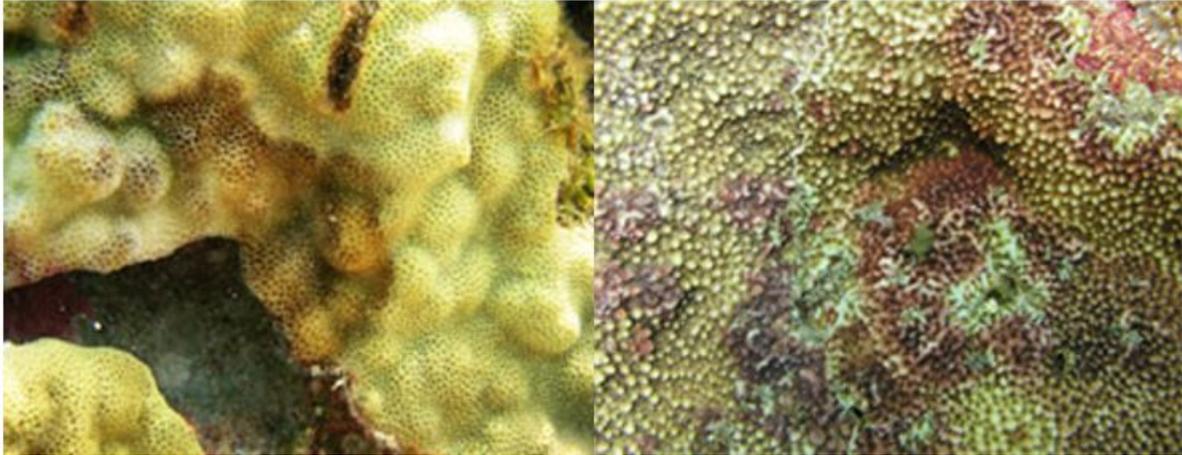


Figure 39. Example of endolithic fungal infection (FUG). NOAA photos.

Skeletal growth anomalies (SGA): Skeletal growth anomalies are characterized by focal to multifocal and circular to irregularly shaped lesions comprising abnormally arranged, enlarged skeletal elements (Figure 40). These anomalies typically protrude above the colony surface and the surface texture visibly differs from healthy tissue. Corallites may be enlarged or remain normal size, but the spacing between corallites may increase. The pigmentation of the anomalies may be normal, slightly pale, or discolored (e.g., pigmentation response).

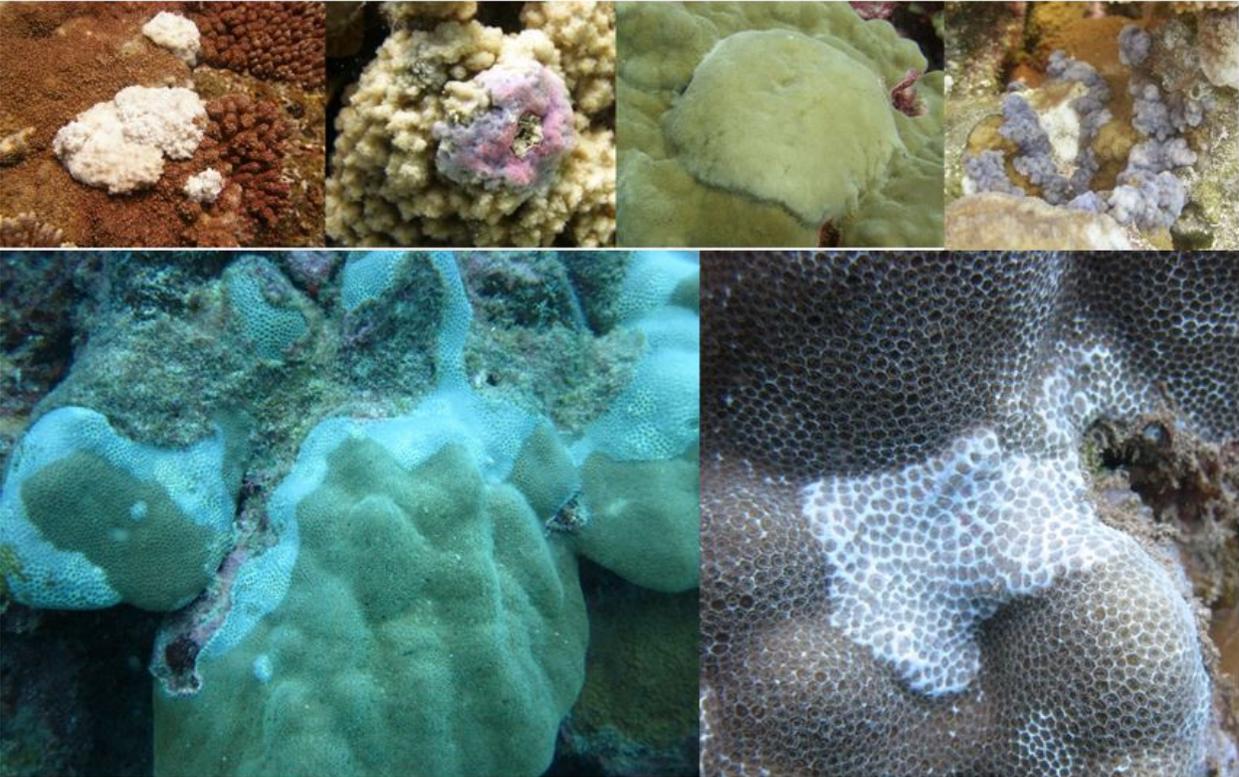


Figure 40. Examples of skeletal growth anomalies (SGA). NOAA photos.

Porites trematodiasis (PTR): This type of lesion is characterized by multifocal, distinct pink to white, small (~5 mm) areas of tissue swelling (Figure 41). The swelling of one or a few polyps is in response to encysted parasitic trematodes. These trematode cysts are often clustered. The extent reflects the amount of colony surface area covered by the pink patches, (i.e., swollen and hyperpigmented). The main host for this disease is the genus *Porites*. Distribution and abundance: Infected colonies are occasional to abundant in the main and Northwestern Hawaiian Islands; absent elsewhere. This disease can be easily be confused with pigmentation responses around tiny spirobid worm burrows, which have tiny tubes coming out of center of hyperpigmented lesion.



Figure 41. Examples of *Porites* trematodiasis (PTR)NOAA photos

Pigmentation response (PRS): Pigmentation response is characterized by bright pink patches of discolored, swollen tissue, often occurring in irregular shapes, scattered on the surface of the colony or adjacent to the sediment/algal margins of a colony (Figure 42). Often these lesions appear to be associated with small areas of tissue loss or filamentous algal infections. Distribution and abundance: Lesions are found on *Porites* and common in the main Hawaiian Islands, Guam, and the southern CNMI; occasional elsewhere.



Figure 42. Examples of pigmentation response (PRS)NOAA photos

Barnacle infestation (BIN): Lesions are characterized by numerous barnacles embedded in a coral colony (Figure 43), resulting in noticeable white spots.

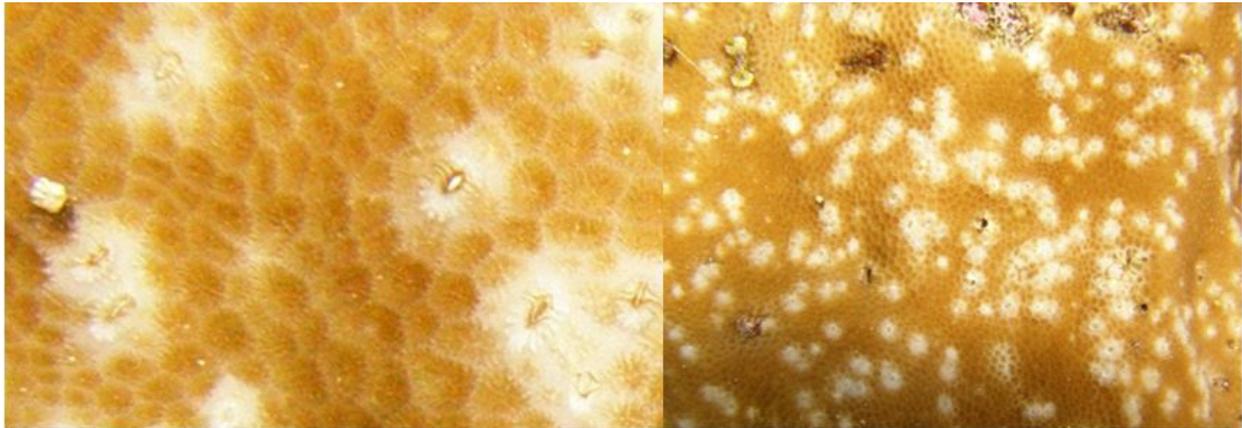


Figure 43. Examples of barnacle infestations (BIN). NOAA photos.

Tube worm infestation (TIN): Tube worm infestations are characterized by numerous tubeworms embedded in a coral colony (Figure 44). There are often noticeable white spots or protruding tubes.

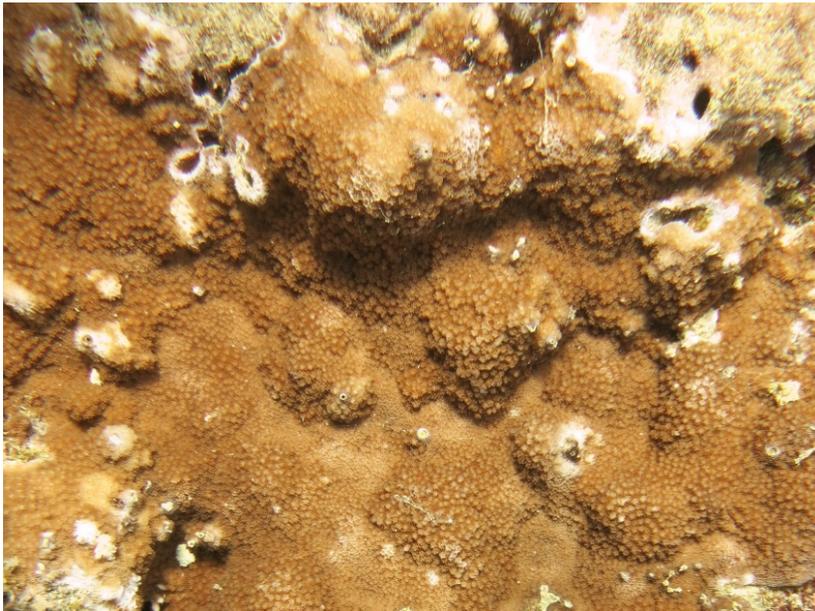


Figure 44. Example of a tube worm infestation (TIN). NOAA photos.

Bleaching (BLE): Coral bleaching is characterized by a reduction or absence of coloration within coral tissues due to the loss of zooxanthellae (Figure 45). Severe bleaching is usually associated with environmental stress, such as unusual levels of temperature, light, and/or salinity. However, coral tissue is still alive, and the polyps are visible. Both the extent (% of colony with reduced pigmentation) and severity (range: 1 = slight paling; 5 = stark white skeleton) are recorded. If

varying severity of bleaching is observed (i.e., a gradient of paling to white), score as the average severity observed over the entire colony.



Figure 45. Examples of coral bleaching (BLE). NOAA photos

Patchy bleaching (BLP): Patchy bleaching is characterized by unusual, diffuse patterns of bleaching that do not appear to be a specific response to thermal or other environmental stress (Figure 46). This condition may be caused by intercellular bacterial pathogens. The coral tissue is still alive, and the polyps are visible. Both extent and severity are recorded. Margins between bleached and unbleached tissue are typically very distinct, while BLE is typically characterized by a gradient with paling present.



Figure 46. Examples of patchy coral bleaching (BLP). NOAA photos

Discoloration other than bleaching or pigmentation response (DIS): Discoloration lesions (other than bleaching and pigmentation responses) are characterized by abnormally colored patches that are often bright and occurring in irregular shapes and patterns. Patches are scattered on the

surface of the colony or adjacent to the sediment/algal margins of a colony (Figure 47). Often these lesions appear to be associated with small areas of tissue loss or filamentous algal infections.

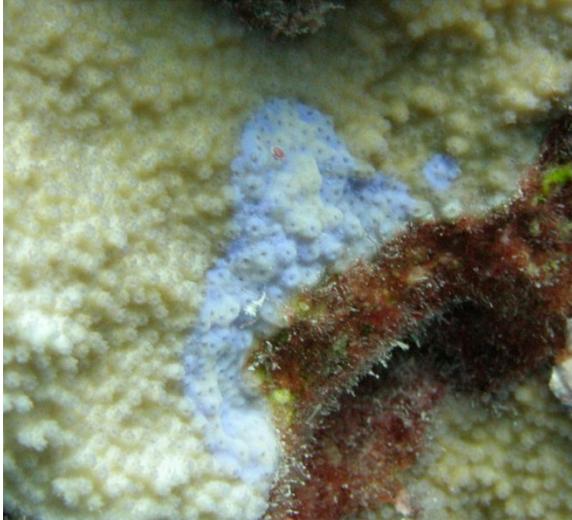


Figure 47. Examples of discolorations other than bleaching (DIS). NOAA photos.

Physical Damage (DAMG)

This includes any physical damage to the colony, including abrasion, breakage, dislodgement, or toppling of the colony. Damage caused by boating and fishing gear (such as nets, chain, line, anchors, etc.) are also included here.

CCA disease surveys

CCA disease occurrence and extent are recorded within the same four segments as the coral conditions listed above. Only two specific CCA diseases are identified; all other observations of CCA disease should be scored as CCA disease general (CCAG). In each segment, CCA disease is identified, and the lesion is measured (max diameter). For example, if four separate lesions of CCA disease are found within a segment, the code CCA is listed on four separate lines of the data sheet under ‘Taxon’, and the disease code (e.g., CFD) is listed under ‘Condition’ with the lesion size listed under ‘Extent’.

Table 6. Categories of CCA disease recorded during adult coral segment surveys.

CCA Disease Category	Code
CCA disease - general	CCAG
Coralline fungal disease	CFD
Coralline lethal orange disease	CLOD
Coralline cyanophyte disease	CCF

Coralline fungal disease (CFD): Characteristics are unlike any other fungal pathogen or black-band disease and are denoted by striated bands that are non-glossy, blue-black color and matte textured (Figure 48). At the time when it was first discovered in American Samoa, this disease co-occurred with coralline lethal orange disease and also primarily attacked *Porolithon onkodes*. Distribution and abundance: common to abundant at Swains Island (American Samoa), Kingman Reef, and Palmyra Atoll (Line Islands); uncommon elsewhere.



Figure 48. Examples of Coralline fungal disease (CFD). NOAA photos

Coralline lethal orange disease (CLOD): Lesions are characterized by a band of bright orange, slimy, stringy material spreading across the algal surface, leaving behind the algal skeletal carbonate remains (Figure 49). Turf and filamentous algae often colonize the bare coralline thallus. Individual lesion sizes vary considerably, but typically range from 1–10 cm in diameter. Distribution and abundance: CLOD is the most abundant of the coralline algal diseases identified, occurring most frequently around American Samoa and Guam, but also in lower abundances in the CNMI and Northwestern Hawaiian Islands.

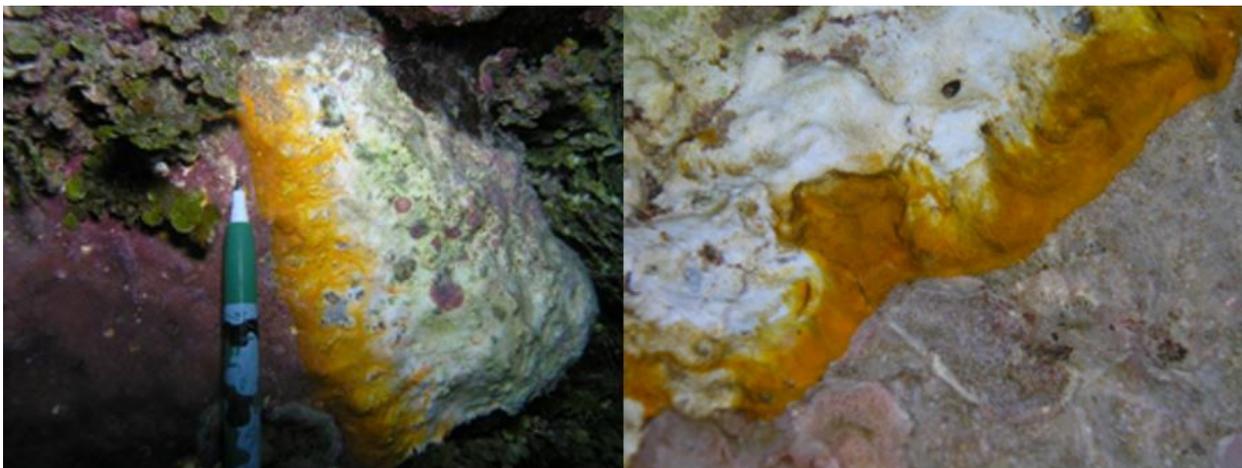


Figure 49. Examples of Coralline lethal orange disease (CLOD). NOAA photos.

Coralline cyanophyte disease (CCD): Lesions are characterized by an irregularly shaped band of slimy, fuzzy, green or tan cyanobacterial material, spreading over the algal surface, leaving behind the bare skeletal carbonate remains; turf and filamentous algae often colonize the bare coralline thallus (Figure 50). Commonly, lesions are distinguishable by the conspicuous appearance of the cyanobacterial mat; bright red, orange, or green discolored coralline algal tissue can be observed in areas where the cyanobacterial mat has been lifted or disrupted. The etiology of CCD is still largely unknown.

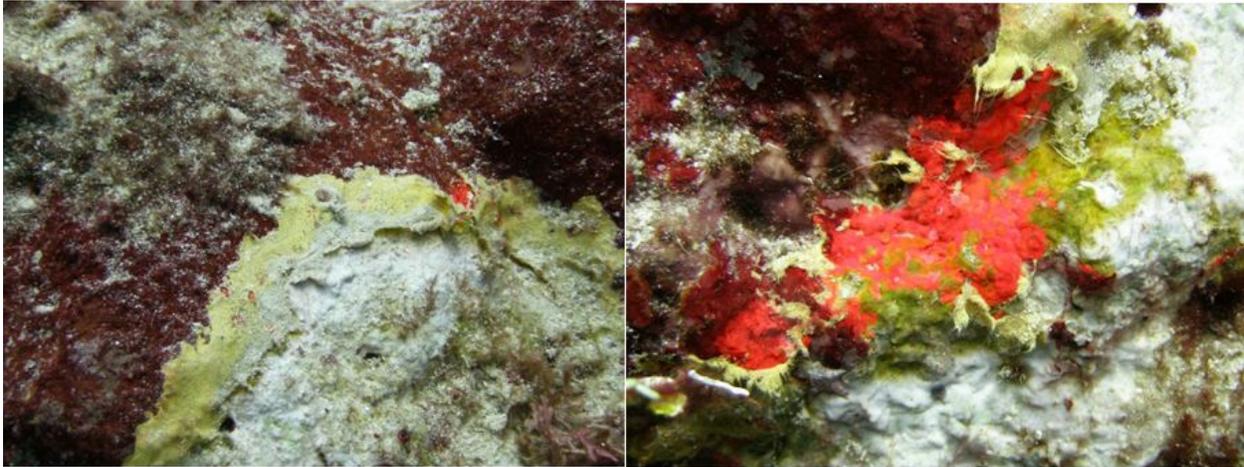


Figure 50. Examples of Coralline cyanophyte disease (CCD). NOAA photos

Presence of Anthozoans

Presence of colonies from the class Anthozoa (Table 7) within each segment should be noted. For example, if one or more colonies of the following genus/species are found within a segment, the species/genus code should be recorded on the data sheet one time. No other information is recorded (i.e., number of colonies and measurements are not recorded).

Table 7. List of Anthozoans to score for presence only.

Subclass Hexacorallia	Code	Order
<i>Palythoa</i> sp.	PASP	Zoantharia
<i>Protopalythoa</i> sp.	PRSP	Zoantharia
<i>Zoanthus</i> sp.	ZOSP	Zoantharia
Corallimorph	CORL	Corallimorpharia
Wire coral	WIRE	Antipatharia
Subclass Octocorallia		
<i>Cladiella</i> sp.	CLSP	Alcyonacea
<i>Dendronephthya</i> sp.	DESP	Alcyonacea
<i>Lobophytum</i> sp.	LOBP	Alcyonacea
<i>Pachyclavularia</i> sp.	PACH	Alcyonacea
<i>Sarcothelia</i> sp.	SRSP	Alcyonacea
<i>Sarcophyton</i> sp.	SARS	Alcyonacea

Subclass Hexacorallia	Code	Order
<i>Sinularia</i> sp.	SISP	Alcyonacea
<i>Stereonephthya</i> sp.	STES	Alcyonacea
Soft coral	SOFT	Alcyonacea
Octocoral	OCTO	Alcyonacea
Subclass Hydroidolina		
<i>Distichopora</i> sp.	DISS	Anthoathecata
<i>Stylaster</i> sp.	STYL	Anthoathecata

Juvenile coral surveys

Surveys of juvenile coral colonies (< 5 cm) are conducted within three numbered 1 × 1 m segments centered along the 18 m transect (Figure 51), where each segment is numbered as follows: **Segment 0** = 0–2.5 m; **Segment 5** = 5.0–7.5 m; **Segment 10** = 1–12.5 m. No juvenile coral survey is performed from 15.0 to 16.0 meters along the transect line.

As with adult colonies, the center of the juvenile colony must be within the boundaries of the segment to be included in the survey. Juvenile colonies should be distinguished in the field by a distinct tissue and skeletal boundary (not a fragment of larger colony). Each colony is measured for size by recording the maximum diameter to the nearest 5 mm.

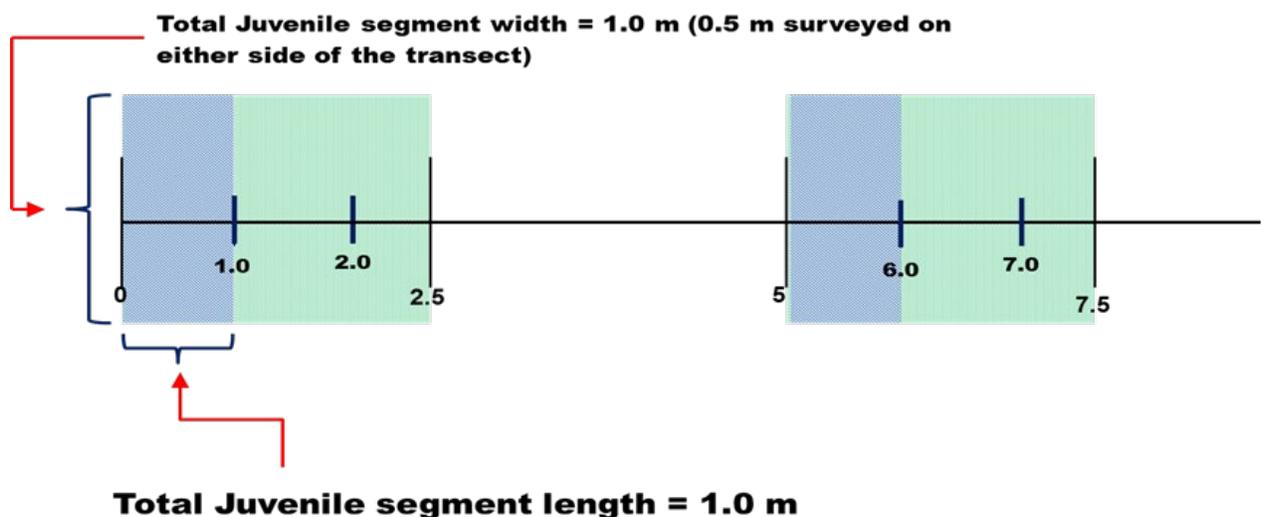


Figure 51. Diagram of two juvenile coral survey segments (blue) in relation to those surveyed for adult corals (green).

Benthic photo surveys

Photoquadrats are used to derive estimates of benthic cover. The photoquadrat consists of a high-resolution digital camera mounted on a photoquadrat pole. Prior to conducting photoquads, review the latest camera settings that are standardized across ESD, and make sure you know how to use the cameras. Prior to each cruise, conduct a photoquad refresher meeting to ensure everyone is up to speed. It is extremely important that we take quality imagery so CoralNet may be used to automatically classify benthic features accurately. All images should be shot in RAW+JPEG. RAW images will be color corrected after the cruise. 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 take a photo of the color card at arm's length. The diver should clearly denote the beginning of each 15-image photo series with 1 and 2 by photographing one finger or two fingers, respectively, before collecting the photoquad images along that transect. The diver should take proper care to photograph the image perpendicular to the reef, not at an angle (Figure 52a). The diver-photographer should look at the camera viewfinder during and after taking pictures to ensure that orientation of the monopod is correct and that the images are not blurry. Fifteen photoquadrat images are collected along each side of the 18 m transect implemented for coral surveys at one meter intervals, starting at 1 m and progressing to the 15 meter mark (images are not collected at the 0 m mark). This provides a total of 30 photoquads per site.

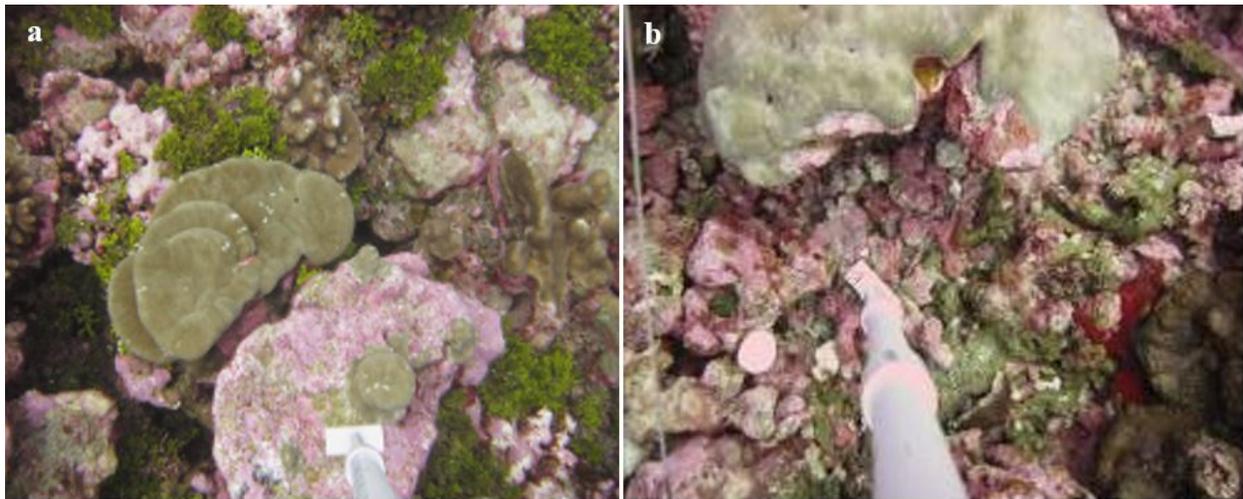


Figure 52. Examples of (a) ideal and (b) incorrect monopod placements. NOAA photos

If the meter stick is crooked (Figure 52b), 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. See T:\Benthic\SOPs & Instructions\Camera Use and Download\Camera Downloads and Managing Optical Data_v4.doc for proper camera download procedures.

Dive and Navigation Information

The Dive and Navigation Information form (Figure 4) is used to record descriptions of benthic REA sites surveyed during each diving operation day. A new sheet should be filled out each day as dives are completed. The sheet is turned in to the data manager at the end of each dive day. These sheets serve as permanent records. The following information is recorded:

- **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 +/- x** (e.g., x equals + 10 hours in the MHI/NWHI; check with the data manager to obtain appropriate value of x per island/jurisdiction)
- **Small Boat:** Current small dive boat (e.g., HI-2, 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., Benthic A).
- **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)
- **Habitat type:** Either taken from the Benthic Data Sheet (Figure 5), 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 this form.
- **Minimum and Maximum Depth:** These are minimum and maximum depth of the site in feet.
- **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 Category.** Recorded as shallow (S), mid-depth (M), or deep (D). Can be abbreviated as S, M, or D. Min and max depth are captured by each diver on the underwater data sheets (Figure 5).
- **Coral belt:** Check if completed
- **Transect Photos:** Initials of the diver that took benthic photos
- **Samples:** Indicate whether water, coral, or algae samples were taken
- **Additional Notes:** This space can be used to record any additional information judged to be important by data collectors.

Archiving Photos

After each day's field operations, benthic images are uploaded to the data server and must be stored in a specific file folder format (detailed in Appendix 2.). 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 ESD server: V:\Cruise\CruiseData\HA1008

MHI\Optical\MOL\REA\BENTHIC\MOL-160. Each REA site folder contains two folders: *Photo_Quads* and *Site_Photos*. In each of these folders are subfolders for each replicate survey (transects 1 and 2), where all benthic and site photos are uploaded. In addition, in an *OTHER* folder at the REA directory level, all photos that are neither benthic photoquad images nor site photos 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 follow instructions in Appendix 2 and 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 Mission Data Application. The diver who collected the data is responsible for the initial data entry and quality control. Quality control should include error checking the entered data against the data sheet 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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Appendices

Appendix 1: Canon Powershot S110 setting

Before each dive day, verify/set these camera settings:

- 1) Set to “P” (Program)
- 2) Set ISO to AUTO: Press ”FUNC SET” (functions will show on the left side of screen) > select “ISO” icon > Select AUTO
- 3) Set image quality to “L”: Press ”FUNC SET” > select “Compression Resolution” icon > select “L”
- 4) Time settings = UTC: Press “MENU” > select camera settings > scroll down to “Date/Time...”
- 5) Set it to NO FLASH

During each dive, verify/set these camera settings:

- 1) White balance:
 - a. Set camera to “P” (program)
 - b. Press ”FUNC SET”
 - c. Highlight “White Balance” icon
 - d. Aim the camera to a white object and press “RING FUNC” once.
- 2) If taking photos in darker/deeper sites or “camera shake warning” shows up on bottom left corner of the screen, adjust ISO setting.
 - a. Press “FUNC SET”
 - b. Highlight ISO icon
 - c. Adjust ISO to 400 or above (Warning: higher ISO results in grainy image. Try not go above 1000)
 - d. Press “FUNC SET”

After each dive day, see instructions for ‘Camera Downloads and Managing Optical Data’.

Appendix 2: Camera downloads and managing optical data

If you took any photos at sites, follow this procedure upon your return on each dive day:

CAMERA DOWNLOADING

The photos in the **CameraDownload** folder is our only assurance that any reconstruction will be successful and that a backup exists in case of a problem with the photos in the months and years after the cruise. Be sure to place all original photos here.

1. Create a new directory in:

**T:\Cruise\
CruiseData\
[Cruise Directory]** (e.g. SS1601_AmSamoa)
**CameraDownload\
ISLANDCODE\
REA\
BENTHIC\
CameraID\
MM-DD-YYYY** (Currently your First Initial and Lastname, e.g. DSwanson)

2. Do not make any corrections to the original photos. This folder needs to remain intact. DO NOT REMOVE ANY PHOTOS FROM THIS FOLDER! Instead copy and paste photos from this folder to the appropriate Optical folder (see below).

3. Check to ensure all photos have been correctly downloaded from the camera before erasing the camera's memory card.

Photo Quad Photos

1. Check to see if the site folder already exists in

**T:\Cruise\
CruiseData\
[Cruise Directory]** (e.g. SS1601_AmSamoa)
**Optical\
ISLANDCODE\
REA\
BENTHIC\
SITE-ID\
SITE-ID** (e.g. PAL-195, in Caps)

2. If a folder has not yet been created for the site, copy and paste the "SITE-ID" folder into the BENTHIC folder and rename it for the site. Please name the site EXACTLY as shown, no spaces, no underline, just ISLANDCODE (all in Caps), a dash, and a three digit number.

3. The following directories should exist under the [SITE-ID] directory:

PHOTO_QUADS (in Capital letters, exactly as shown)

A (and B) (Capitalized, either A or B)

Copy photos from the newly created CameraDownload folder into the appropriate folders (A = transect 1, B = transect 2); if you took additional benthic photos make sure to delete any extras (**there should be exactly 15 photos in each folder**).

SITE_PHOTOS

Download site photos into the SITE_PHOTOS folder. It's okay to have more than four site photos.

If you have other noteworthy Misc. Photos at the site, create a new folder (directory) using your First Initial and Lastname in:

FI_LASTNAME and put a copy of the photos in this folder

Data Entry

1. For each site where you took Photo Quad images, check the **TRANSECT_PHOTOS_YN** box in the Coral Data Entry Site sub-screen for that site.
2. For each transect where you took Photo Quad images, but no survey was completed, create a survey entry and uncheck the **SURVEY_DONE_YN** box in the Coral Data Entry Transect sub-screen for that transect.

What do I do if?

Issue	Resolution
You have less than 15 photos for a PHOTO_QUAD Transect...	Add a note to this effect in the notes column on the Benthic Survey Data Sheet (?) or Dive and Navigation Data sheet (?) just before you enter your transect observations
You have too many photos for a PHOTO_QUAD transect...	Ensure all photos are actually photo quad images (occasionally slate images are erroneously included). If all are legitimate images, delete images until only 15 remain
You put a photo quad image in the SITE_PHOTOS folder...	Delete the image from the SITE_PHOTOS folder as duplicate images will be detected and create an error when processed
You notice that you've copied the same photos to two different sites...	Look back in the CameraDownload folder and recopy both folders to the correct directories.
A Survey was done on a transect, but Photo_Quads were not taken	Uncheck the <input type="checkbox"/> TRANSECT_PHOTOS_YN box in the Coral Data Entry Site sub-screen for that transect and corresponding paper datasheets?

Purpose of Downloading Photos:

- Once the files have been copied to the server, a script is run on them to rename the photos to reflect the cruise and site they were taken so that they can be analyzed for various reasons. The script keys it's renaming off of the folder structure, which it interprets strictly (using the naming conventions outlined in this document). It also expects 15 photos in the PHOTO_QUADS directory and specific flags to be set in the Data Entry

Database. Any deviation from the above listed procedure will produce an error that will need to be corrected (either the folder names need to be corrected, the number of files needs to be adjusted, or the Data Entry database needs to be corrected). All errors must be corrected before the cruises photos can be released for analysis.

- Following these instructions with precision is important and will save you, your Team Lead, the Data Manager, and likely several other individuals up the processing chain a good bit of time if they have to reconstruct and reformat what you have done. At each point in the process, the potential exists to render the photos you took unusable simply because they were not put in the right place or were given the wrong name.

Appendix 3. Data entry QC checklist

After benthic REA data has been entered into the ESD Data Entry Application database, check the adult (a) and juvenile (b) data for the following:

Adults

- 1) Correct date? Site? Transect? Segment? Please double check your data entry for the correct transects and segments. This is one of the most common errors. If someone helps you complete the survey of a segment, ALL of the data from the segment should be entered under one diver and NOT separately by both divers.
- 2) Check segment length and width. Did you survey the whole segment?
- 3) Verify that the Anthozoans (other cnidarians including Alcyonareans, Zoantharians, coralliomorphs and Antipatharians) presence boxes are checked for the relevant genera or groups found in the segment.
- 4) Scroll down your list of entries for the segment. Do you have the same number of colonies as on your data sheet?
- 5) Did you enter a value for recent dead %? If so, there **has** to be a cause identified – BOTH Recent dead general and recent dead specific. (e.g. 5 % recent dead, recent dead general = DZGN, Recent dead specific= WSY)
- 6) Did you enter a category for condition? If so, there has to be an extent value entered (% of colony affected). Do you need a severity (BLE, BLP, SGA, and PTR)?
- 7) Do you have any entries with maximum diameter (L) less than 5 cm? If so, do you have the condition recorded as damage —broken, toppled etc.? Or do you have a note in the comments that indicates a fragment?

Juveniles

- 1) Correct date, site, transect, and segment? Remember: Transect 1 and 2 for adults = transect 3 and 4 for juveniles, respectively. Please double check your data entry for the correct transects and segments. This is one of the most common errors.
- 2) Check segment length and width. Did you survey the whole segment?
- 3) Is L greater than W for all entries? Maximum diameter (L in the data entry program) should be the largest measurement recorded and entered.
- 4) Are all entries for L less than 5 cm?
- 5) Scroll down your list of entries for the segment. Do you have the same number of colonies as on your data sheet?

Appendix 4. Benthic survey training worksheet

Rapid Ecological Assessment (REA) Benthic Survey Training Worksheet

Name:

Date:

1. How do you distinguish juvenile colony from an adult colony; or an asexual fragment?
2. What are the three things that you must write on each of your data sheets?
3. Give a few examples or list the type of features that you would use to characterize a site.
4. List the segment dimensions and locations on each transect used for surveying adult coral colonies.
5. List the segment dimensions and locations on each transect used for surveying juvenile coral colonies.
6. How do you distinguish old dead from recent dead?
7. Is sedimentation a condition or a cause of recent mortality?
8. How do you distinguish recent dead caused by gastropod predation from recent dead caused by acute tissue loss/ white syndrome (disease)?
9. If a coral colony is fragment and there is no discernable recent dead partial mortality, how would you record the relevant information on your datasheet?
10. If you secure the end of transect 1 to a dead coral branch but you have to use part of the actual tape so that segment 0 actually starts at 0.2 m, what are the dimensions of segment 0; or what is the location of segment 0 on the transect tape?