

AGRRA PROTOCOLS VERSION 5.4

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INTRODUCTION

The goals of the Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program are to assess important structural and functional attributes of tropical Western Atlantic coral reefs and to provide fisheries-independent estimates of fishing intensity. Data from AGRRA-sponsored surveys, or which have been collected independently and submitted to the program, are processed, archived, and posted online at regular intervals (see: www.agrra.org).

AGRRA sites are surveyed in a probabilistic fashion to yield information representative of large areas, such as shelves, islands, countries or ecoregions, *i.e.*, at the scales over which many reef structuring processes and impacts occur. Rapid sampling of numerous sites across a stratified-random seascape with a small number of non-fixed, transect-based, visual surveys has been shown to provide a more accurate and spatially representative estimate of large reef areas than is given by detailed sampling of many transects at only one or several sites (Murdock and Aronson, 1999; Kramer, 2003; S. Smith *et al.*, mss.; see also T. Smith *et al.*, 2008).

Since the program was first introduced in 1998, we have learned more about sampling design, the spatial distribution of Caribbean-area reefs, and the spatial and temporal scales of processes affecting these reefs. As a result the AGRRA protocols are continuing to adaptively change while enhancing comparability between our indicators and those of many other coral reef survey programs (*e.g.*, Hill and Wilkinson, 2004; Miller, 2005; Miller *et al.*, 2008; Brandt, 2009; Obura and Grimsditch, 2009; Florida Reef Resilience Program, 2009a).

In a major change, the original AGRRA benthos protocol now is partitioned into two components, simplifying the tasks required of surveyors and increasing the efficiency of underwater data collection. The additional information that is gained outweighs the loss of direct equivalence with some indicators measured in earlier versions of the protocol.

Groups are now encouraged to set their own level of survey effort anywhere between *basic* (for novices and some management needs) and *detailed* (some research needs). When deciding which level to adopt within each survey method, groups should consider their own goals and objectives, the time or funding available for the surveys and subsequent analyses, logistical support constraints, as well as the scuba and taxonomic skills of the participants.

The number of trained divers that are needed to complete an assessment in one dive will depend on the desired level of survey effort, on the depth and geomorphology of the habitat, and on the abundance, size, and diversity of its corals, algae and fishes. We recommend a minimum of six divers, *i.e.*, two for the fish censuses, and two for each of the new benthic and coral surveys. Larger numbers are appropriate for training purposes and with student groups. Whenever possible, we urge the inclusion of a supplementary diver to make a video and/or photographic record of each transect and of additional interesting features at the survey site.

Shallow (< 4 - 5 m) AGRRA surveys were initially conducted by snorkeling. SCUBA is now recommended for all assessments, unless the water is less than about 1.5 m deep or the shallow habitat is very depauperate (*i.e.*, currently not a constructional coral reef). The additional expense is more than repaid because the divers are less fatigued and consequently more alert when transcribing their data later in the day.

Given the small spatial extent of many reefs in the tropical Western Atlantic, and to minimize incidental coverage of non-reefal (*e.g.*, sand, seagrass) habitats, transect lengths remain at 10 m for the benthic and coral protocols and at 30 m for the fish protocol. Lead-core rope is retained for the coral and benthic transects to reduce swaying and to maintain comparability with earlier AGRRA surveys. Visual census transects remain the core of the fish protocol; roving diver surveys have been moved to the expanded **OPTIONAL COMPONENTS**. The transect numbers given for each protocol are the minimum considered necessary for statistical analyses. When the number of divers is larger than the minimum, the transect number may be correspondingly increased.

SELECTING SURVEY SITES

An AGRRA **site** is situated in a geomorphic **zone** of a **reef** on an insular or continental **shelf** (as defined by Sullivan and Bustamanate, 1999) within one of the 12 marine shelf **ecoregions** of the Tropical Northwestern **province** of the Tropical Atlantic biogeographic **realm** delineated by Spalding *et al.* (2007).

A **site** is defined as a more or less homogeneous habitat, roughly 200 m × 200 m in spatial extent, and accessible from a boat or by swimming from shore. The method for selecting sites will be influenced by the size, abundance, distribution and habitat complexity of the reefs in the study location. What follows are our recommended procedures, but we fully understand that modifications may be necessary to accommodate the special conditions of a given assessment. All such changes should be carefully noted on the UW (underwater) datasheets and DataEntry spreadsheets.

If the spatial extent, habitat complexity, and/or number of reefs in the study location (shelf, island or country) are so limited that all prominent habitats can be surveyed within a reasonable time frame, there is no problem. More commonly, however, the reefs will need to be subdivided or **stratified** and representative examples randomly selected from among one or several strata. The most obvious stratifiers are geomorphic characteristics that are influenced by cross-shelf position (*e.g.*, shelf-edge barrier or bank reefs, lagoonal or mid-shelf patch or linear reefs, nearshore fringing reefs), orientation (*e.g.*, windward or leeward exposure), depth, slope, etc.

Zones of maximum reef development that are highly recommended for AGRRA surveys include shallow (< ~5 m) reef crests, many of which were previously constructed by *Acropora palmata*, and intermediate-depth (~5 - 15 m) linear or patch reefs that are dominated by large massive corals like the *Montastraea annularis* species complex. (Information on *A. palmata* is particularly relevant nowadays, even when most of the corals are dead and/or their borders are unclear and point counts substitute for individual colony assessments.) If these habitats are locally absent, rare, or physically inaccessible, try to select others with an abundance of reef-building corals. Wherever possible avoid hardgrounds, pavements or bedrock that lack constructional reef frameworks, and depths below about 20 m.

Sites are **randomly** chosen for survey after the reefs in a location have been stratified by habitat. One method is to number each distinct reef and use a random method to select the ones to survey. For continuous bank-barrier or fringing reefs that are several km or more long, **sites** can be located by randomly choosing among a grid of 200 × 200 m squares superimposed over the reef in a map, remote image or GIS product (Fig. 1).

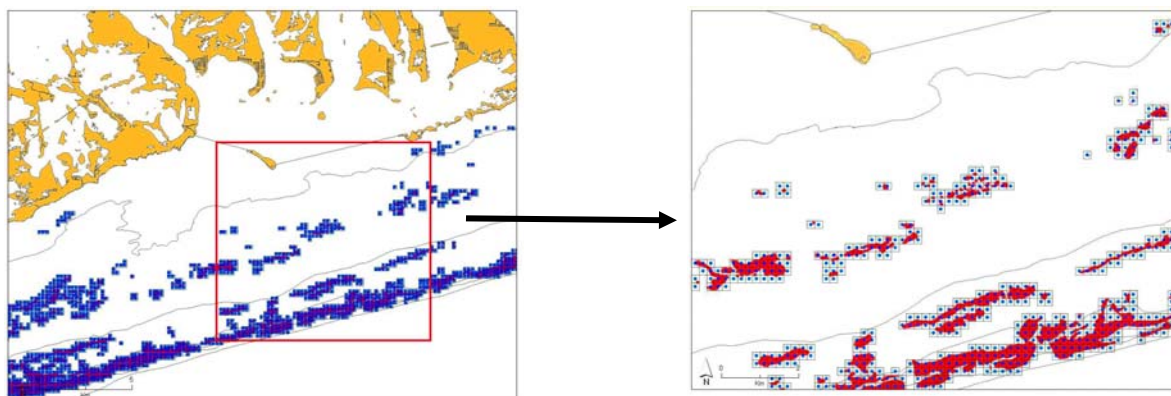


Figure 1. 200 m × 200 m grid over reef habitats (From Florida Reef Resilience Program, 2009b).

If accurate coral reef habitat maps are available in digital GIS format, more sophisticated sampling designs can be developed that are spatially balanced and fully representative using the generalized random tessellation sampling (GRTS) approach (Stevens & Olson, 2004) or 2-stage stratified random sampling (Cochran, 1977).

For those with access to ESRI's ArcGIS 9.2 or higher, in addition to providing stratified random sampling, the NOAA Biogeography Branch Sampling Design Tool can also generate sampling points after previously collected data are analyzed to compute sample size requirements or efficiently allocate samples among strata (see: <http://ccma.nos.noaa.gov/products/biogeography/sampling/welcome.html>).

Load the randomly chosen sites onto at least one GPS unit (two units safeguard against unexpected battery failures in the field), and use them to navigate to the locations. Unless you are sure that the habitat to be surveyed occurs within a radius of about 100 m of each randomly selected site, we recommend having alternate, randomly chosen, “backup” sites available in case some sites in the initial selection are found to be unsuitable (*i.e.*, the habitat was misclassified) or it proves too dangerous to survey due to inclement weather (Fig. 2).

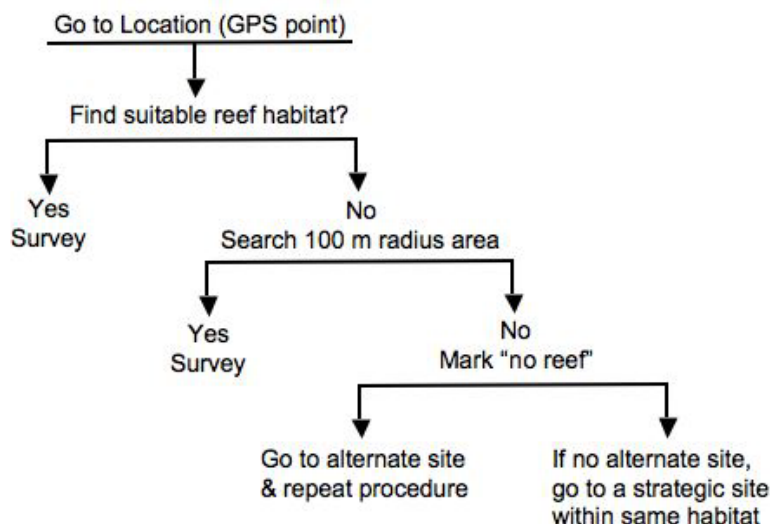


Figure 2. Site-selection decision tree. (Adapted from Florida Reef Resilience Program, 2009b).

Alternatively, it may be necessary to survey sites that are chosen *strategically* for some special purpose: because they are considered degraded, threatened, or in particularly good condition; to compare an MPA or fishery reserve with an unmanaged “control” or fishing area; to be located off every headland or village, or at some predetermined distance (such as every 30 km) along a coastline or bank margin. Although this has not always been possible in the past, strategic sites should be analyzed separately from randomly chosen sites.

The minimum number of randomly chosen sites to survey in each habitat increases as its spatial area in the study location increases, *i.e.*, S. Cuba > N. Jamaica > Bonaire (*e.g.*, Miller *et al.*, 2008). On the assumption that surveys are conducted in two zones/shelf (equivalent to the reef crest and deeper) that are usually of unequal spatial area, Table 1 approximates the minimum sample size (= number of survey sites) for selected Caribbean-area shelf units. Estimates of reef areas were provided by The Nature Conservancy and are based on the Millennium Coral Reef Mapping Project’s geomorphic reef classification (see <http://imars.usf.edu/corals/>). For areas in which the reefs are not visible in the Millennium Maps (mostly narrow, inshore fringing reefs) or otherwise not given in Table 1, a minimum of five sites should be sampled within each chosen habitat stratum.

It is critical to record the exact location of the actual site with a GPS. Whenever a survey takes place immediately below a stationary boat, simply record its position once the boat has stabilized. If the survey will occur some distance from a boat (typically the case when surveying a reef crest) or from shore (when swimming from land), note the distance and direction from the recorded GPS location so that a more accurate position can be approximated later.

Table 1. Minimum number of survey sites/shelf in the tropical northwestern Atlantic, assuming two zones that are usually of unequal area/shelf (adapted from Ault and Smith, 2007).

Shelf Unit	Target # of sites	Shelf Unit	Target # of sites	Shelf Unit	Target # of sites	Shelf Unit	Target # of sites
Grand Bahama	58	NW Cuba	78	Anguilla	14	Central Panamá	10
Abaco	82	SW Cuba	15	Saba	16	West Panamá	10
Berry Islands	18	Isle of Youth	87	Antigua	13	Gulf of Mosquito	59
Bimini	12	South Central Cuba	10	Montserrat	10	South Costa Rica	10
Cay Sal Bank	39	SE Cuba	301	Guadeloupe	28	Nicaragua	132
Andros	43	Little Cayman	10	Dominica	10	Corn Islands South	18
New Providence	18	Grand Cayman	12	Martinique	19	Corn Islands North	21
Exumas Eleuthera	155	North Jamaica	37	St. Lucia	12	San Andres West	20
Long Island	27	South Jamaica	44	Barbados	11	Nicaragua Rise	113
Southern Great Bahama	35	Pedro Bank	33	St. Vincent	10	Swan Islands	10
East Bahama	13	East Jamaica	35	Grenada	21	North Honduras	10
East Acklins	10	Morant Cays	10	Trinidad Tobago	11	Bay Islands	30
Acklins Crooked	18	South Haiti	30	Blanquilla	10	Guatemala	33
East Crooked	10	West Haiti	40	Isla La Tortuga	10	Belize	68
Little Inagua	16	North Hispaniola	47	Los Roques East	10	Offshore Belize	67
North Inagua	10	NE Dominican Republic	26	Los Roques Central	46	South Yucatan	49
Great Inagua	22	East Dominican Republic	21	Los Roques West	12	Chinchorro	41
Grand Turk	41	South Hispaniola	14	West Venezuela	10	Cozumel	28
East Caicos	10	North Puerto Rico	26	Curaçao	10	North Yucatan	49
East Cuba	69	South Puerto Rico	27	Bonaire	10	Central México	10
NE Cuba	56	USVI BVI	43	Aruba	12	Dry Tortugas	34
North Cuba	19	St Croix	13	East Panamá	68	Ocean Florida Keys	14

EQUIPMENT

The following equipment is required for **each diver** in addition to basic snorkeling and SCUBA gear (including depth gauge):

- a clipboard or UW slate (see size specifics below) and pencils
Attach at least one pencil to the clipboard or your wrist with a series of interconnected rubber bands or string; always carry a spare pencil somewhere secure.
- UW datasheets (see below), with rubber bands or clips to fasten to the clipboard or slate
*The datasheet templates can be photocopied with a laser printer onto **both** sides of underwater “DuraCopy” Copier/Laser Paper 6511. Although expensive (about US \$65 from online distributors for 100, 8.5" × 11" sheets in January, 2010), this paper is highly recommended. Your data are more likely to be entered correctly because the appropriate template is present on every datasheet.*
- glasses or contact lenses if needed
If you normally correct your vision on land, especially if you are far sighted, it is important to have a diving mask with the correct prescription lenses, or to wear your contacts when diving. Otherwise you may not be able to distinguish some important details while doing the surveys.

Benthic Survey divers will need:

- a *letter-sized* clipboard or UW slate and pencils
- copies of the **Basic** or **Detailed BENTHIC-UW-V5.4** datasheet printed on UW paper
Attach to the slate or clipboard with rubber bands, clips or bungee cord.
- **optional for detailed-level:** a copy of the **CORAL Codes-V5.4** list printed on UW paper
Attach to the reverse of the slate or clipboard with the rubber bands, clips or bungee cord.
- a lead-core rope (= transect line) marked with colorful (not black) cable ties at **10-cm** intervals for a distance of 10 m, and to which a tie-off loop is attached at each end
5 mm/3/16" or 6 mm/1/4" diameter lead-core rope (e.g., Duraflex leadline) is available at commercial fishing supply stores or cooperatives. Using a metric tape or meter stick for scale, carefully add conspicuously colored cable ties at 10-cm intervals along the line. Distinguish the meter marks (be sure to include 0 and 10) with a different color from that of the cable ties marking the 10- to 90- cm marks within each meter. (If you use thick cable ties, you can number their position along the line with a Sharpie.) Remove the “tail” of each attached cable tie with a clipper (Fig. 3).

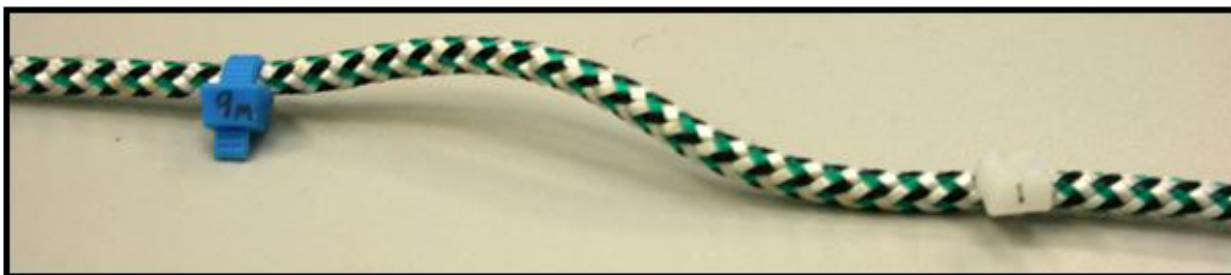


Figure 3. Lead-core rope with numbered cable ties. (J. Richardson, photo)

- a 1-m long pole marked in 10-cm intervals
Use a narrow PVC pipe (available at hardware stores). Paint or tape a scale along the pipe at increments of 10 cm.
- a small, thin, metric plastic ruler (**detailed-level surveys only**)
Trim the ruler to have a tapered point but still be legible at its basal 5 cm. Drill or punch a hole at the other end of the ruler, and either tie it to the clipboard or slate, or attach it to your wrist with a series of interconnected rubber bands.

- a 25 cm × 25 cm quadrat to which a hook has been attached
Construct the quadrat of narrow (12mm/1/2" diameter) diameter PVC pipe with 90° elbow connectors (available at hardware stores) to have an inner length of 25 cm and drill holes to let the air escape underwater (Fig. 4A).

For convenience in swimming: hook the 10-m end of the transect line to the quadrat (Fig. 4A) and wrap it tightly around the quadrat; then tie the 0-m end to one side of the quadrat. Insert the poles and clipboard through the center, as illustrated in Fig. 4B.

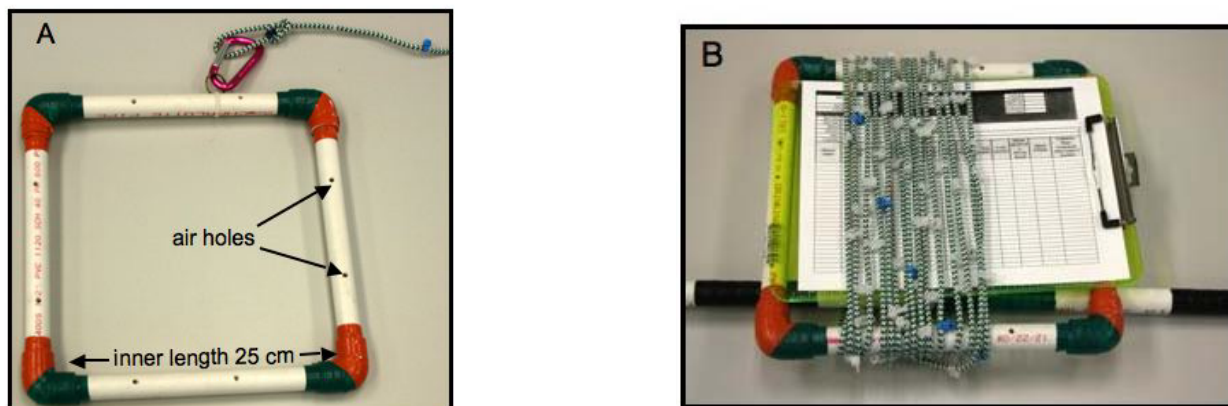


Figure 4. (A) Quadrat with hook attached to the transect line; (B) Benthic equipment “kit.” (J. Richardson, photos)

Coral Survey divers will need:

- a *letter-sized* clipboard or UW slate and pencils
- copies of the **Basic** or **Detailed CORAL-UW-V5.4** datasheet printed on UW paper
Attach to the slate or clipboard with rubber bands, clips or bungee cord.
- **optional:** a copy of the **CORAL Codes-V5.4** list printed on UW paper
Attach to the reverse of the slate or clipboard with the rubber bands, clips or bungee cord.
- a lead-core rope (= transect line) marked with colorful (not black) cable ties at **1-m** intervals for a distance of 10 m, and to which a tie-off loop is attached at each end
5 mm/3/16" or 6 mm/1/4" diameter lead-core rope (e.g., Duraflex leadline) is available at commercial fishing supply stores or cooperatives. Using a metric tape or meter stick for scale, carefully add colorful cable ties (remove their “tails with a clipper) or electrical tape at 1-m intervals along the line.
- a 50-cm long pole marked in 10-cm intervals, with 5-cm increments at each end
- a 1-m long pole marked in 10-cm intervals
Use narrow (12mm/1/2" diameter) PVC pipes (available at hardware stores) for both poles. Paint or tape a scale along each of the pipes.
- a small (15 cm) ruler (optional)
Drill or punch a hole at one end of the ruler, and either tie it to the clipboard or slate, or attach it to your wrist with a series of interconnected rubber bands.
- a 25 cm × 25 cm quadrat to which a hook has been attached
Construct the quadrat of 12 mm/1/2" diameter PVC pipe with 90° elbow connectors (available at hardware stores) to have an inner length of 25 cm and drill holes to let the air escape (Fig. 4A).

For convenience in swimming: hook the 10-m end of the transect line to the quadrat (Fig. 4A) and wrap it tightly around the quadrat; then tie the 0-m end to one side of the quadrat. Insert the poles and clipboard through the center, as illustrated in Fig. 4B (but note only the 1-m pole is shown).

Fish Survey divers will need:

- a 15 cm/6" × 23 cm/9" UW slate (*e.g.*, a REEF slate or equivalent)
The slate should be mounted on the T-bar (see below) to facilitate carrying the equipment.
- copies of the **Basic** or **Detailed FISH-UW-V5.4** datasheet printed on UW paper
Attach to the slate or clipboard with rubber bands, clips or bungee cord.
- **optional for detailed-level:** a copy of the **FISH List-V5.4** list printed on UW paper
Attach to a separate slate or place under the fish datasheets on the above slate.
- a graduated T-bar with a 60-cm long handle and two, equal-length arms marked in 10-cm intervals providing a total width across the top of 1 m
Use 18 mm/3/4" diameter PVC pipe and a T-connector (available at hardware stores). Attach the T-connector to one end of the handle pole (Fig. 5A). Paint or tape a scale in increments of 10 cm along each arm pole and on the top of the T-connector. Drill a hole on the end of each arm in order to attach them to the T-connector with a piece of bungee cord or string (Fig. 5B).
- a D-ring or clamp attached to your weight belt or BCD
- a weighted, 30 m/100 ft, fiberglass transect tape
Attach a 1 kg/1-3 lb weight at the free end of the tape. Put a clip on the reel to attach it to a D-ring on your BCD or weight belt (Fig. 5C).

For convenience in transport and storage, disconnect the arms from the T-connector and fold them down beside the handle (Fig. 5D).

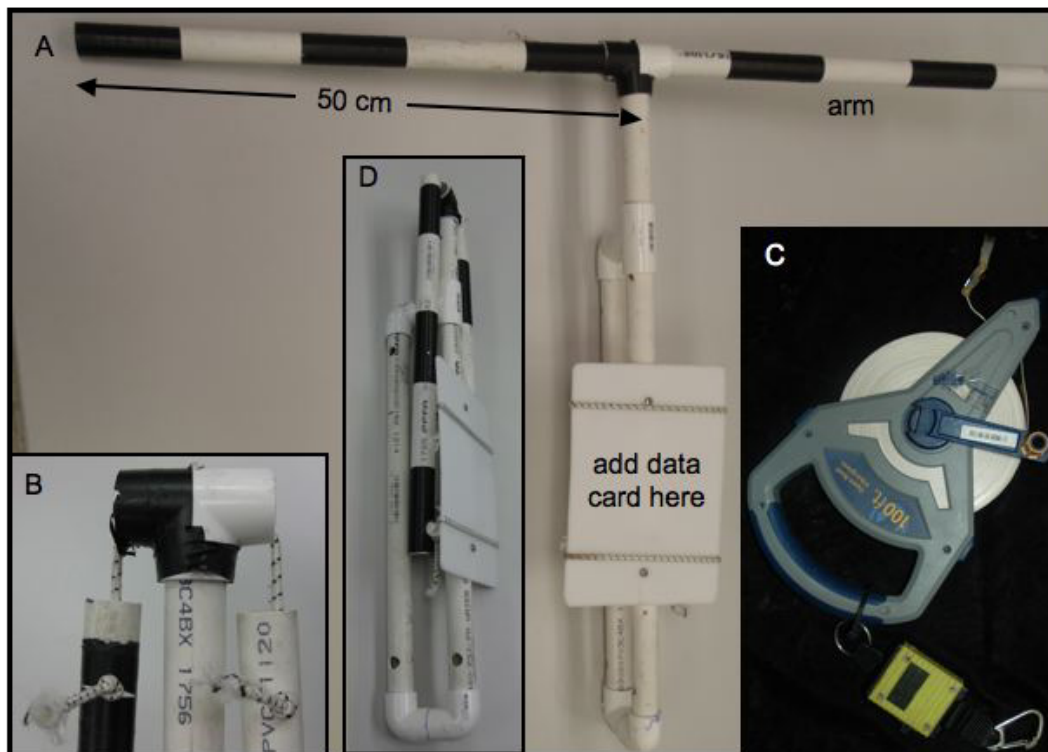


Figure 5. (A) Assembled T-bar; (B) Close-up of two arms attached with bungee cord to the T-connector; (C) a tape reel; (D) T-bar closed for transport and storage. (J. Richardson, photos A,B,D; A. Harrison, photo C)

SURVEYS

I. AGRRA Benthic Survey (minimum 2 divers)

Objectives

- Record benthic cover under points at 10-cm intervals on each of six, 10-m long transect lines.
- **Detailed-level only:** Measure macroalgal heights to approximate their biomass (Steneck and Dethier, 1994) and ecological impact (as cover × height).
- Count all ≤ 2 cm coral “recruits,” and note the substratum type in each of five, 25 cm × 25 cm quadrats placed at 2-m intervals along each transect line.
- Count all juvenile and adult long-spined urchin (*Diadema antillarum*, a key herbivore), commercially important Caribbean spiny lobster (*Panulirus argus*) and queen conch (*Strombus gigas*), invasive Indo-Pacific lionfishes (*Pterois* spp.), and identify any trash in a 1-m wide belt centered on each transect line.

New in Version 5

- A. Point counts, each with a corresponding code, have been substituted for the benthos intercept length measurements used in Version 4 of the AGRRA protocols.
- B. Lionfish counts, plus identification of trash and predominant algae, have been added to the belt transects.

Unchanged in Version 5

- A. Small corals (“recruits”) and substratum type are recorded with the quadrat.
- B. As in Version 4, small *Diadema* with black-and-white banded spines are considered to be “juveniles.” Larger urchins with all-black spines or with all-black spines alternating with all-white spines or, more rarely, with all-white spines, are scored as “adults.”

Point-count identification effort levels

Benthic organisms chosen for AGRRA Version 5 surveys are grouped primarily by their ecological interactions with the reef-building corals and crustose coralline algae that construct reefs. Many groups (macroalgae, corals, other sessile invertebrates) can be surveyed at more than one taxonomic level to accommodate differing programmatic requirements, time available underwater, and levels of participant expertise.

Basic: primary groups of reef constructors (corals, crustose coralline algae) and major groups of organisms that kill and overgrow corals and/or prevent settlement of coral larvae (Table 2).

Table 2. Categories, codes and rationales for **basic-level** benthic point-count surveys.

CATEGORY	CODE	RATIONALE
Live corals (name if you can)	LC	Construct coral reefs; universal reef condition indicator
Bleached (live) corals	BLC	Indicate altered reef conditions (often thermal stress when large scale)
Newly dead corals (bright white skeleton; name if you can)	NDC	May indicate ongoing disease, bleaching, predation, competition, or other perturbation(s)
Crustose coralline algae	CCA	Construct or cement reef framework; may indicate good conditions for recruitment of coral larvae
Conspicuous (“nuisance”) cyanobacteria	CYAN	May indicate altered reef conditions (possibly nutrients, temperature, few herbivores); may kill/overgrow corals or prevent coral larval recruitment
Turf algae ¹	TA	Eaten by many herbivorous fishes; when thick or tall indicate few herbivores; thick TA mats trap sediment and inhibit coral larval recruitment, plus kill/overgrow corals and crustose coralline algae (CCA)
Macroalgae	MA	All are eaten by some herbivorous fishes; some inhibit coral larval recruitment or kill/overgrow corals and CCA; may provide refuge for some coral predators or be a repository for some coral pathogens
Aggressive invertebrates	AINV	Kill/expand over corals and CCA as they grow
Other invertebrates	OINV	Epibenthic invertebrates that usually don’t kill/expand over corals and CCA as they grow

¹ Multispecific assemblages of red, green, and brown algae and cyanobacteria, usually short (<2.5 cm tall) and often filamentous.

Detailed: live and newly dead corals by their CARICOMP-based codes (for species, the first letter of the genus name followed by the first three letters of the species name; see **CORAL Codes-V5.4** list), and other organisms to at least genus level when possible (Table 3) or to the taxonomic level specified for the survey.

Table 3. Categories, codes and rationales for **detailed-level** point-count benthic surveys.

CATEGORY	CODE	RATIONALE
CORALS Live coral by species (or genus) name Bleached (live) coral by species (or genus) name Newly dead coral by species (or genus) name	4-letter coral code BL-coral code ND-coral code	Construct coral reefs; universal reef condition indicator, <i>e.g.</i> , PAST = <i>P. astreoides</i> ; AGAR = <i>Agaricia</i> sp. Indicate altered reef conditions (often thermal stress when large scale) <i>e.g.</i> , BL-MCOM = fully bleached <i>M. complanata</i> May indicate ongoing disease, bleaching, predation, competition, or other perturbation(s), <i>e.g.</i> , ND-CNAT=newly dead <i>C. natans</i>
OTHER CALCIFIERS Crustose coralline algae OR distinguish <i>Porolithon pachydermum</i> Newly dead crustose coralline algae ¹ Calcified worm tubes Peyssonnelid algae ²	CCA POR ND-CCA CWT PEY	Construct or cement reef framework; may indicate good conditions for recruitment of coral larvae May indicate ongoing disease; outbreaks have occurred on some reefs Potential coral larval recruitment site Rarely contribute to reef construction or binding; unlikely to be coral larval recruitment sites
MISCELLANEOUS Sediment (at least 2.5 cm/1 inch thick) OR distinguish as sand or mud Hard surface OR distinguish as dead coral or pavement Rubble Unknown, invisible (<i>e.g.</i> , in a hole)	SED SAND or MUD ROCK DC or PV RB XXX	Subtract from total as not a potential coral larval recruitment site, ignore associated epibenthos (<i>e.g.</i>, macroalgae) Potential coral larval recruitment site; often considered “barren,” but probably covered with biofilms of bacteria, diatoms and/or other microalgae Subtract from total as not a potential recruitment site for most reef corals; ignore associated epibenthos (<i>e.g.</i>, turf algae, macroalgae) Subtract from total as no specific information of any effects on corals or their larvae
“ALGAE” Conspicuous (“nuisance”) cyanobacteria Turf algae Turf algae-sediment mat Fleshy macroalgae OR <i>Dictyota</i> OR <i>Lobophora variegata</i> OR name of any other common FMA	CYAN TA TAS FMA DIC LOB name or create a code , <i>e.g.</i> , SAR = <i>Sargassum</i>	May indicate altered reef conditions (possibly increased nutrients, temperature, few herbivores); may prevent coral larval recruitment or kill/overgrow corals and crustose coralline algae (CCA) Eaten by many herbivorous fishes; when thick or tall indicate few herbivores Thick TA mats can trap sediment, inhibit coral larval recruitment, and may kill/overgrow corals and CCA All are eaten by some herbivorous fishes although some are chemically defended; some inhibit coral larval recruitment or kill/overgrow corals and CCA; may provide refuge for some corallivores or be a repository for some coral pathogens May inhibit coral larval recruitment or kill small corals and CCA Inhibit coral larval recruitment, can kill/overgrow some corals (especially small ones) and CCA, generally avoided by fishes As for FMA

¹ Visible as orange tissues or freshly exposed white skeleton around green algae in dead skeleton.

² If uncertain of identity, scratch the surface with a sharp instrument: crustose coralline algae have white skeletons and the skeletons of peyssonnelids are dark.

Table 3, continued.

CATEGORY	CODE	RATIONALE
Calcareous macroalgae OR <i>Halimeda</i> OR <i>Halimeda</i> mat ³ OR <i>H. goreauii</i> mat OR <i>H. opuntia</i> mat OR name of any CMA	CMA HAL HAM HGM HOM name or create a code (as above)	Have calcareous (and some have chemical) defenses against herbivorous fishes; at least a few inhibit coral larval recruitment or kill/overgrow corals and CCA; may provide refuge for some corallivores or be a repository for some coral pathogens As for CMA Inhibit coral larval recruitment; probably kill whatever they overgrow; avoided by some fishes; good refuge for some corallivores; may be a repository for some coral pathogens As for CMA
Mixtures of fleshy & calcareous macroalgae	FMA-CMA or names or create codes (as above)	Will be scored 0.5 as FMA and 0.5 as CMA
INVERTEBRATES		
Aggressive invertebrates OR <i>Chondrilla caribensis</i> ⁴ OR <i>Cliona</i> OR <i>Cliona delitrix</i> OR zooxanthellate clionid OR <i>Briarium asbestinum</i> OR <i>Erythropodium caribaeorum</i> OR <i>Palythoa caribaeorum</i> OR <i>Trididemnum solidum</i> OR name any other overgrowing invertebrate	AINV CHON CLIO CDEL ⁵ CZOO ⁶ BRI ERY PAL TRI name or create a code (as above)	Kill/expand over corals and CCA as they grow As for AINV As for AINV + bioeroding activities weaken coral skeletons As for CLIO As for CLIO As for AINV As for AINV As for AINV As for AINV As for AINV
Other Invertebrates OR Epibenthic sponge OR Gorgonian holdfast OR name of any other OINV	OINV SPO GOR name or create a code (as above)	Epibenthic invertebrates that usually don't kill/ expand over corals and CCA as they grow As for OINV As for OINV As for OINV

³ *Halimeda* mat = dense clump of *Halimeda* that traps sediment

⁴ formerly called *Chondrilla nucula*

⁵ tissues are bright red-orange

⁶ several species; tissues are brown or black

Benthic Method

See also the summary/reminder Instructions in the appropriate BENTHIC UW datasheet file.

Begin by choosing the appropriate level (*basic* or *detailed*) of effort for each section of the protocol. Before starting to survey, conduct **consistency-training exercises** with other benthic team members or an instructor to gain practice in setting and retrieving the lead-core transect line, in locating points on the substratum, assigning them to the AGRRA point-count categories that were chosen for inclusion in your surveys, and learning their corresponding codes. For **detailed-level surveys**: practice measuring macroalgal heights (plus algal turf and cyanobacterial heights if required for the particular surveys).

Retraining on a weekly basis during expeditions is strongly encouraged.

1A. At each site, record the following information on your **Basic** or **Detailed** BENTHIC-UW-V5.4 datasheet before the dive:

Surveyor: 4-letter code with first two letters of your first and last names

Date: Day with two digits/abbreviation of month name/year with two digits (*e.g.*, 14 Aug 07)

Site Name: Local survey site name (if known) or description of area (*e.g.*, off Windy Hill Pt.)

Day #: sequential by day during an expedition (1, 2, 3, etc.)

Site #: sequential within each day (1, 2, 3, etc.)

AGRRA Code: sequential site code, as 3 letters + 2-3 digits (*e.g.*, BAH01, BAH02, BAH03 = first three Bahamian surveys) during an expedition

Latitude & Longitude: as determined by DGPS (or best available instrument) at the site, **to be corrected if necessary from a boat or other fixed position** (see Selecting Survey Sites)

Reef Type: (e.g., bank, barrier, mid-shelf, fringing, patch)

If different from expected, please describe the reef type surveyed.

Reef Zone: (e.g., back = lagoon-ward or landward of a crest; crest; fore = seaward of a crest or shore)

If different from expected, please describe the reef zone surveyed.

Subzone/Habitat: (e.g., reef flat/*complanata*, inner terrace/brain corals)

If different from expected, please describe the habitat surveyed.

Selection Method: (e.g., stratified random, stratified strategic)

Site Comments: space to describe how latitude and longitude were calculated (e.g., on site or approximated from some fixed position), or other notes about the site—**to be completed by the end of the dive.**

- 1B. Attach a copy of the **CORAL Codes-V5.4** list printed on UW paper to the underside of your clipboard if needed for reference.
2. At the survey site, use a haphazard method to choose a starting point for your first transect, *i.e.*, by spinning several times with your eyes closed, or gently dropping your meter pole while descending—the latter to be avoided if a current is present or you are near deeper water.
 3. Record when you begin to set the first transect in **Start Time** and, if you can, the **Bottom Temperature** at the depth of the survey habitat. Write #1 in the first Transect # box. Loop the free end of the line to a dead piece of coral or other secure object that wouldn't easily be damaged. Note the **Start Depth** at the initial (=0 m/0 cm) mark and the depth scale (specify as feet or meters). Without biasing your choice of direction by looking down, unwind the line from the quadrat as you swim away from this starting point.

Be careful not to cross benthic transects that are being set by other divers. Unless directed to survey there by your team leader, avoid the edges of the reef or unusual reef features, and areas with abrupt changes in slope, deep grooves, large patches of sand, or unconsolidated coral rubble.

As soon as the entire transect line has unreeled, pull tightly to ensure that it is taut, and secure to the bottom by wrapping the quadrat around or over some sturdy object. Note the **End Depth** at the 10-m mark.
 4. As you return towards the starting point, you may need to straighten the line by repositioning one of its ends, by pulling it off the bottom in high-relief reefs, or by disentangling it from upright gorgonians, sponges, etc.

*In some locations you will need to keep a lookout for lionfishes (*Pterois spp.*). Should any be present and remain in the immediate vicinity, pay attention to their specific locations during your survey!*

Benthic Cover-Point Counts

- 5A. Starting at the initial mark, swim back above the line, recording what you see on the substratum immediately below each of the 10-cm marks, ending at the 9m/90 cm point. If the line sways due to strong surge or bottom current, note its position in the middle of its swing when locating the 10-cm points.

By entering the category codes in the vertical rows matching the 0-90 marks in each meter, you can easily retrace your route to locate any missing points at the end of each meter—and then enter the appropriate code(s) in the remaining blank box(es).

If the reef has high relief, and you are unable to locate the position of the point(s) to count on the substratum by simple visual inspection:

In a **narrow** space, hold the pole vertically below its position on the line and record what is beneath the pole.

Above a **wider** expanse of sand or pavement, note on your UW datasheet which intervals are involved. If sand, record as such and move on. If pavement, place your measuring pole on the substratum under the line.

Record what is immediately adjacent to each 10-cm mark on one side of the pole across the predetermined interval (e.g., if from 4.5 - 5.3 m, for a total of 9 points).

Basic-level: use the **BASIC** codes listed at the base of your UW datasheet and any additional codes considered necessary for the survey site.

Detailed-level: use the CARICOMP-based codes for corals, the **DETAILED** codes (as required) for other organisms and any additional codes required for the survey site.

If you need to create additional codes for locally abundant organisms, be sure to write an explanation in the Transect comments box (e.g., MIC = *Microdictyon*; BAR or XES = the barrel sponge, *Xestospongia muta*).

Benthic Cover-Algal Heights

5B. **Detailed-level only:** In the first transect of each surveyor, for a total of 2 transects per site, use the tapered ruler to measure the height of all macroalgae (or group of mixed macroalgae) under the 10-cm points to the nearest 1 cm if > 1 cm tall or to the nearest 0.5 cm if < 1 cm tall. For encrusting macroalgae (i.e., decumbent forms of *Lobophora* and *Padina*), measure the thickness of the blade(s) to the nearest 0.1 cm (each blade being about .1 cm thick) rather than their length along the substratum. Record as name/height (e.g., DIC/.5 = 0.5 cm tall *Dictyota*; FMA-CMA/4 = 4 cm tall, mixed fleshy and calcareous algae).

Optional: *Similarly measure the heights of any cyanobacteria (as done for macroalgae) and algal turfs (to the nearest 0.1 cm) beneath the points.*

Recruits and Substratum

6A. When the point counts are finished, unhook the 25 cm × 25 cm quadrat and, if necessary to maintain its position, attach the transect line by its tie-off loop to an object that isn't easily damaged. Swim back along the transect line, temporarily centering the quadrat on the substratum at intervals of two meters (i.e., under the 10-, 8-, 6-, 4-, and 2-, or the 9-, 7-, 5-, 3-, and 1- meter positions).

Within each quadrat, use your hands to brush loosely attached algae and sediment off the substratum, and then look for small, up to **2 cm** maximum diameter, coral **recruits** (all scleractinians and *Millepora*). Note that practice and good eyesight (or corrective lenses) are needed to be successful in finding coral recruits due to their small size and inconspicuous appearance.

If the quadrat lands in an area of high topographical complexity, search everything that you can see within the frame, regardless of its orientation relative to the reef's planar surface (Slingsby, 2003).

Basic-level: tally (= count and record) the total number of small corals in each quadrat; write NONE if you see no recruits.

Detailed-level: in each quadrat, tally as many of the recruits as you can to the genus or species level using their respective coral codes; code unknowns as UK. Write NONE if you see no recruits.

6B. Record the predominant **substratum** type within each quadrat as one of the following:

LC = live coral

DC = dead coral

PV = pavement

RB = rubble

SAND = sand

Other = none of the above, or identify by name or by species code

If two substratum types are of approximately equal abundance, record both with a slash between the two codes (e.g., LC/PV will be scored as a 0.5 each for live coral and pavement).

Motile Invertebrates, Lionfish and Trash

7A. Using the 1-m pole perpendicular to the line transect for horizontal scale, swim a 0.5-m wide belt transect along one side of the line. Ignoring other motile invertebrates, tally every "juvenile" and "adult" long-spined urchin (*Diadema antillarum*), plus all Caribbean spiny lobster (*Panulirus argus*), **live** queen conch (*Strombus gigas*), lionfish (*Pterois* spp.–try to estimate the size as total length) and items of trash that you see between the initial (= 0 cm) and end (= 10 m) marks. If the line sways due to strong surge or bottom current, note its position in the middle of its swing when positioning the pole.

*Inspect all shelter-providing spaces (e.g., crevices, bases of large corals) within the belt. If you turn over *Strombus* shells that are upside-down to look for the living animal, be sure to replace the shell in its original, upright position.*

7B. Return to the starting position by swimming a second, 0.5-m wide belt transect along the other side of the transect line. Continue to tally all juvenile and adult *Diadema*, Caribbean spiny lobster, queen conch, lionfish and trash. Put a 0 in the box corresponding to any animal for which none are seen.

Predominant Algae, Other Benthic Organisms and Transect Comments

8. Note, for the belt as a whole, the predominant algal type if crustose corallines or algal turfs. If macroalgae dominate, try to identify to genus (*e.g.*, LOB for *Lobophora*) or species (*e.g.*, HGOR for *Halimeda goreauii*).

If any other group of benthic organisms within the belt transect is conspicuously perturbed by bleaching, disease, predators, etc., record in the transect comments box:

its name or AGRRA code

its approximate abundance by cover or number

the approximate percent or number affected by the perturbation

(*e.g.*, 10% MALC/90% BL = *M. alcornis* covers 10% of the substratum and 90% of the colonies are bleached; seafan, 7/20 CYANS = 7/20 *Gorgonia* colonies are being overgrown by cyanobacteria.)

Record any other interesting observations in the Transect Comments box.

9. Take the quadrat to the 10-m end of the transect and hook it to the end of the line, then wrap the line around the quadrat as you swim to the 0-cm end and release its tie-off loop.

10. Repeat steps 2-9 until a total of six transects has been completed at the survey site (*e.g.*, three transects each if two divers). Try to stay at least 5 m away from all other benthic and coral transect lines.

Routine measurements of macroalgal heights should be limited to two transects. However, at sites in which macroalgae are scarce or very patchy in distribution (i.e., less than about 10 % cover), should time permit, surveyors are encouraged to measure their heights on all six transects.

After completing the last transect, tie the loop at the 0-m end of the wrapped transect line to one side of the quadrat.

Record the number, and approximate size (as total length), of any lionfishes outside the area of your belt transect in the Site Comments box.

11. After diving, enter all your data and comments on a daily basis into a copy of the appropriate **Basic** or **Detailed BENTHIC-DataEntry-V5.4** spreadsheet. (The Day # and Site # information can help order the UW datasheets.) Be sure to explain any codes of your own invention used in the point counts or comments.

Use a **separate** copy of the spreadsheet for **every site (not every day or every expedition)**, and **check your transcribed data to verify its accuracy**. Back up your own data regularly and store it in a safe place.

12. Once the team leader has signed off on all your spreadsheets, and safely stored all the original UW datasheets, the data are ready to be emailed to data@agrra.org for processing, archiving, and possible posting online at the AGRRA web site.

II. AGRRA Coral Surveys (minimum 2 divers)

Objectives

- Assess the size and overall condition of the ≥ 4 cm corals (all Scleractinia and *Millepora* except *Millepora alicornis*) in two, 10×1 m² belt transects.
- **Detailed-level only:** estimate percent partial colony mortality and bleaching condition on the outward-facing surfaces of these corals.

New in Version 5

- Corals should be consistently identified by their CARICOMP-based codes which, for species, is the first letter of the genus name followed by the first three letters of the species name (*e.g.*, *Diploria strigosa* = DSTR).
- Small corals were underrepresented in earlier AGRRA surveys because narrow line transects are biased towards sessile organisms with large diameters (Fig. 6; see also Zvuloni *et al.*, 2008), and because the minimum size for individual assessments was either 25 cm (routine in Version 2) or 10 cm (standard in Versions 3 and 4). Substituting 1-m wide belts, and counting **all** corals that are ≥ 4 cm in maximum length in each of two, 10×1 m² belts allows calculations of their population density, size structure and size-specific condition.

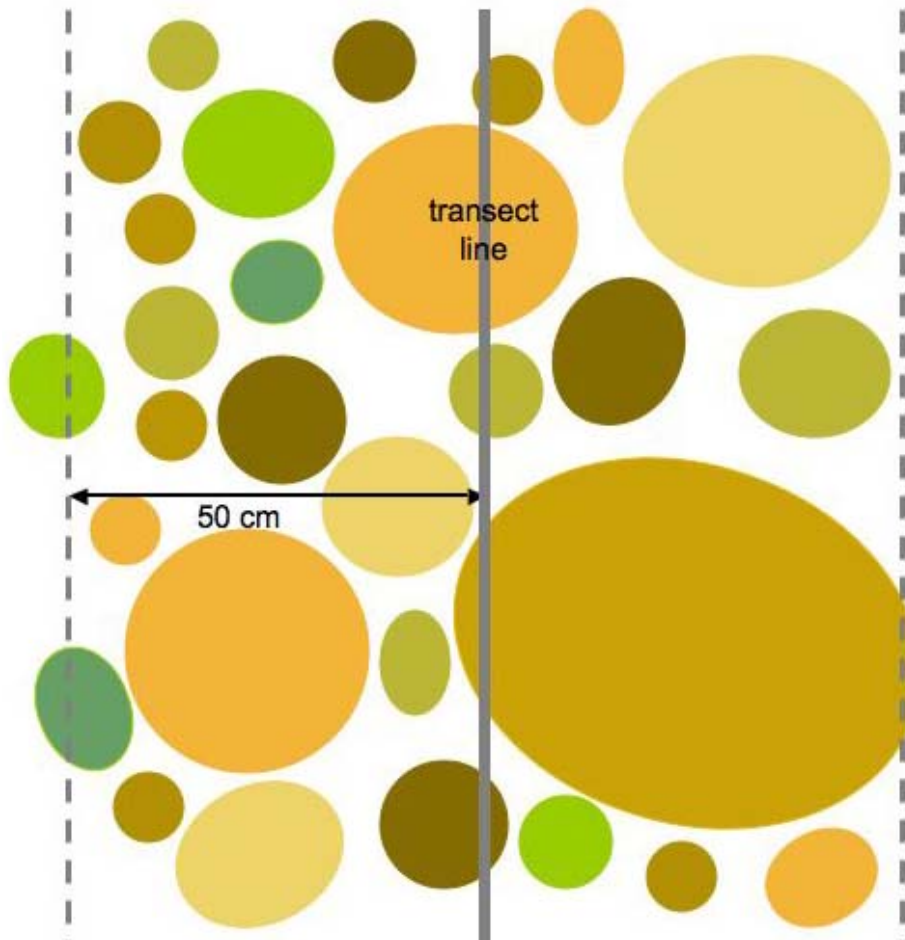


Figure 6. Conceptual diagram of how small size corals are undersampled in line transects relative to 1-m wide belt transects due to their low probability of being located beneath a transect line (After Ault and Smith, 2007).

- C. The number of isolated patches of soft tissue (Florida Reef Resilience Program, 2009a) resulting from external perturbations rather than from natural growth processes (Fig. 7) is a new category for AGRRA that reflects on-going or prior disturbance processes (R. van Woesik, pers. comm.). Isolate number is likely to increase after major, partial-colony mortality events like outbreaks of disease or severe mass bleaching.



Figure 7. Large colony of *Diploria strigosa* with three soft tissue isolates resulting from partial-colony mortality. (K. Marks, photo)

- D. Recent mortality as originally defined in the AGRRA benthos protocol is now partitioned as:
- New mortality (NM)**—non-living part(s) of the coral in which the corallite (= surficial skeletal) structures are still intact, unless they have just been bitten by a fish or abraded, and the freshly exposed, white surface is free of any sediment, microbial/diatom biofilms, other microalgae, etc. The coral's soft tissues would have died within the previous minutes-several days at most and, in some cases, may not have completely sloughed off the skeleton.
- New mortality gives important temporal information during prolonged disturbances like the outbreaks of disease that can follow mass bleaching events (Kramer, 2003).*
- Transitional mortality (TM)**—any non-living parts of the coral in which the corallite structures are slightly eroded at most, unless they have just been bitten by a fish or abraded, and its surface is covered by a thin layer of sediment, or by biofilms of bacteria (including photosynthetic cyanobacteria) and possibly diatoms or other microalgae, or by tiny turf algae. The coral's soft tissues are presumed to have died within the previous day(s)-months.
- Old mortality (OM)** is still defined as any non-living parts of the coral in which the corallite structures are: (a) covered over by organisms that are not easily removed (*e.g.*, thick turf algae, dense macroalgae, attached invertebrates, possibly including other corals); or (b) the overgrowing organisms (and perhaps the outer corallite structures) have been removed by a scraping herbivore (*e.g.*, the stoplight parrotfish *Sparisoma viride*), or abraded by a storm, exposing the underlying skeleton. The coral's soft tissues are presumed to have died within the previous months-years or decades.
- Standing dead (SD)** is used to describe a coral that, for any combination of mortalities (NM, TM and/or OM), is completely (100%) dead over its *entire surface* (*i.e.*, not just on the outward-facing surface).
- E. The prevalence of corals exhibiting partial mortality on any surface is recorded to enhance comparability of the AGRRA dataset with other programs. Partial mortality estimates as a percentage of the outward-facing coral surfaces are now restricted to *detailed-level surveys*.
- F. Similarly the percent of the outward-facing surface of the coral that is **pale** or **bleached** (as defined below) is now restricted to *detailed-level surveys*. Bleaching prevalence on any surface is noted in all surveys.

- G. Diseases. The list of “common field names” for coral diseases and syndromes in our region has expanded considerably (Weil and Hooten, 2008; Bruckner, 2009; E.C. Peters, pers. comm., 2009; see also Bruckner, 2002; Raymundo et al., 2008; www.coris.noaa.gov/about/diseases). Moreover, nomenclatural changes necessitate the recoding of a white acroporid disease (see below):

Conspicuous Tissue Loss–

CBD = Colored Band Diseases, **or distinguish as:**

BB = Black Band

RB = Red Band

CCI = Caribbean Ciliate Infection

WDS = White Diseases or Syndromes, **or distinguish as:**

Non-acroporids:

WP = White Plague

CWS = Caribbean White Syndromes (*i.e.*, not white plague, not on *Acropora*)

Acropora only:

AWDS = Acroporid White Diseases or Syndromes, **or distinguish as:**

WB = White Band

WPD = White Patch Disease (formerly coded as WS)

RTL = Rapid Tissue Loss (*i.e.*, diffuse, irregular patterns that differ from WB and WPD)

Conspicuous Tissue Discoloration–

DS = Dark Spots Syndrome

YB = Caribbean Yellow Band (= yellow blotch)

Conspicuous Tissue Anomalies

GA = Growth Anomaly (*i.e.* depression or bulging mass with no polyps, or with unusual, chaotic polyps)

GI = Gigantism (*i.e.*, unusually large polyps)

Unchanged in Version 5

- A. In AGRRA surveys, a **colony** has distinct margins and is considered to represent one genetic individual. Colonial corals have “an autonomous mass of skeleton covered with living tissues” (Nugues and Roberts, 2003), even if the soft tissues naturally subdivide into separate units (*e.g.*, the lobes of *Montastraea annularis*). A **clump** (thicket or cluster) is a large group of similar appearing, conspecific corals that are usually branching (*e.g.*, *Acropora*, *Porites*, *Madracis*) or lobate (*e.g.*, *M. annularis*), and for which individual colony borders cannot be distinguished by visual inspection underwater. **Fragment** refers to a detached, possibly broken, and easily moved coral that is unlikely to remain for long in its current position on the reef. **Solitary** corals of the genus *Scolymia* that are large enough for inclusion in AGRRA surveys are rare in most shallow-intermediate depth habitats and should be assessed with the colonies.
- B. As in Version 4 of the AGRRA benthos protocol, the width of a colony or clump is defined as its maximum distance orthogonal to the maximum length (maximum length being equal to the maximum diameter of Versions 1-3).
- C. Bleaching is characterized by approximate severity of discoloration as:
P = Pale relative to what is considered “normal” for the species, geographic location, depth, habitat and season.
BL = Bleached (tissue is fully bleached, no zooxanthellae are visible).
Remember that many severely bleached corals are transparent, but you can still see the polyp tissues above the skeleton. Some fully bleached corals are pale purple, blue, or pink, in addition to being transparent.
Bleached tissues are alive and do not represent new mortality.
- D. Percent partial mortality estimates are restricted to the outward-facing coral surfaces for reasons of greater simplicity, speed and estimation accuracy (J. Lang, pers. obs.). Estimates of percent partial mortality that include the entire coral are not *directly* comparable with the AGRRA data.

Coral proficiency effort levels

Basic: CARICOMP-based coral codes, tissue isolates number, size measurements, mortality prevalence (if any), and any conspicuous signs of disease or bleaching.

Detailed: as above for *basic-level*, plus percent of any partial mortality or bleaching of the outward-facing surface (if a colony) or under points (if a clump), field names for all locally common coral diseases and, optionally, names of predators, competitors or other common sources of mortality.

Coral Method

See also the summary/reminder Instructions in the appropriate CORAL UW datasheet files.

Begin by choosing the appropriate level (*basic* or *detailed*) of effort for each section of the coral protocol. Before starting to survey, you should conduct **consistency-training exercises** with other coral team members or an instructor to gain practice in setting and retrieving the lead-core transect line, identifying corals underwater, in determining coral boundaries, measuring their sizes, counting any tissue isolates, and in recognizing mortality categories, signs of disease, bleaching, or other conspicuous local perturbations. For *detailed-level surveys*: also practice estimating percent partial mortality and bleaching of the outward-facing coral surfaces, and identifying coral diseases, signs of predation and competition.

Retraining on a weekly basis during expeditions is strongly encouraged.

- 1A. At each **site**, record the following information on your **Basic** or **Detailed** CORAL-UW-V5.4 datasheet before the dive:
 - Surveyor:** 4-letter code with first two letters of your first and last names
 - Date:** Day with two digits/abbreviation of month name/year with two digits (*e.g.*, 14 Aug 07)
 - Site Name:** Local survey site name (if known) or description of area (*e.g.*, off Windy Hill Pt.)
 - Day #:** sequential by day during an expedition (1, 2, 3, etc.)
 - Site #:** sequential within each day (1, 2, 3, etc.)
 - AGRRA Code:** sequential site code, as 3 letters + 2-3 digits (*e.g.*, BAH01, BAH02, BAH03 = first three Bahamian surveys) during an expedition
 - Latitude & Longitude:** as determined by DGPS (or best available instrument) at the site, **to be corrected if necessary from a boat or other fixed position** (see Selecting Survey Sites)
 - Reef Type:** (*e.g.*, bank, barrier, mid-shelf, fringing, patch)
If different from expected, please describe the reef type surveyed.
 - Reef Zone:** (*e.g.*, back = lagoon-ward or landward of a crest; crest; fore = seaward of a crest or shore)
If different from expected, please describe the reef zone surveyed.
 - Reef Subzone/Habitat:** (*e.g.*, reef flat/*complanata*, inner terrace/brain corals)
If different from expected, please describe the habitat surveyed.
 - Selection Method:** (*e.g.*, stratified random, stratified strategic)
 - Site Comments:** space to describe how latitude and longitude were calculated (*e.g.*, on site or approximated from some fixed position), or other notes about the site—**to be completed by the end of the dive.**
- 1B. Attach a copy of the **CORAL Codes-V5.4** list printed on UW paper on the back of your clipboard if needed for reference.
2. At the survey site, use a haphazard method to choose a starting point for your transect, *i.e.*, by spinning several times with your eyes closed, or gently dropping your meter pole while descending—the latter to be avoided if a current is present or you are near deeper water.
3. Record when you begin to set the first transect in **Start Time** and, if you can, the **Bottom Temperature** at the depth of the survey habitat. Loop the free end of the line to a dead piece of coral or other secure object that wouldn't easily be damaged. Note the **Start Depth** at the initial meter mark and the depth scale (specify as feet or meters). Without biasing your choice of direction by looking down, unwind the line from the quadrat as you swim away from this starting point.
Be careful not to cross benthic transects that are being set by other divers. Unless directed to survey there by your team leader, avoid the edges of the reef or unusual reef features and areas with abrupt changes in slope, deep grooves, large patches of sand, or unconsolidated coral rubble.

As soon as the entire transect line has unreeled, pull tightly to ensure that it is taut, and secure to the bottom by wrapping the quadrat around or over some sturdy object. Note the **End Depth** at the final meter mark.

- As you return towards the starting point, you may need to straighten the line by repositioning one of its ends, by pulling it off the bottom in high-relief reefs, or by disentangling it from upright gorgonians, sponges, etc.

In some locations you will need to keep a lookout for lionfishes (Pterois spp.). Should any be present and remain in the immediate vicinity, be sure pay attention to their specific locations during your survey!

By the end of your dive, note the number and approximate size (as total length) of any lionfishes in the Site Comments box (if outside the area of your belt transect) and/or the Transect Comments box (if within your belt transect).

- Using the 1-m pole perpendicular to the transect line for horizontal scale, swim a 0.5-m wide belt transect along one side of the line. Examine all scleractinians and *Millepora* (**except *M. alcicornis***) that are ≥ 4 cm in maximum length and for which any part the coral, **no matter how small**, is located **inside the belt** (as recommended by Zvuloni *et al.*, 2008), including all those which underlie the transect line.

Remember to ignore all corals that are < 4 cm in maximum length.

All ≥ 4 cm Corals

Species. Identify each colony, clump or fragment using its 4-letter coral code. Include all entirely dead corals that can be identified at least to genus and are still mostly intact. Ignore dead branching corals that have lost most of their branches as their sizes would be grossly underestimated.

Isolates. For each **colony**, record the total number of isolated patches of soft tissue resulting from **external perturbations**. Put 1 if no such disruptions, and zero if standing dead. If > 10 isolates, estimate to the nearest 5 as 15, 20... *etc.* Do **not** include isolates that form naturally in some lobate corals like *Montastraea annularis*, in phaceloid corals like *Mussa angulosa* and *Eusmilia fastigiata*, or in branching corals like *Porites porites* and *Madracis auretenra* (formerly *M. mirabilis*).

For each **clump** or **fragment**, write CLUMP or FRAG, respectively. Don't count their isolate numbers.

All Colonies and Clumps (ignore fragments)

Size. For each colony or clump, measure the **maximum length** and the **maximum width** of the outward-facing surface (both are perpendicular to its axis of growth) as seen from above in planar view, and its **maximum height** (parallel to the axis of growth) as seen from the side. Use the 50-cm pole or a ruler for small corals, and the 1-m pole for large corals and clumps. Try to record these measurements to the nearest 1 cm up to 10 cm, to the nearest 5 cm up to 50 cm, and to the nearest 10 cm when > 50 cm.

Colony margins can be difficult to recognize when parts of a coral have died and are overgrown by other organisms—particularly other corals of the same species. Look for connected live tissues, basal skeletal connections, and at the size and color of the separated tissues.

How to assess colonies or clumps that are detached from the substratum:

If **loose**, and large enough to remain in place during all but severe storms, the size measurements and condition assessment should be made as if still attached (Fig. 8A). You can write LOOSE in the corresponding Comments box.

If **loose but wedged** (*i.e.*, likely to remain in this position for an extended period), measure as if attached in its “new” position (Fig. 8B); you can write WEDGE in the corresponding Comments box.

If **fallen and reoriented** to grow upward in a new position, measure the “new” size dimensions (Fig. 8C), and use the “new” outward-facing surface for estimating % mortality or bleached.

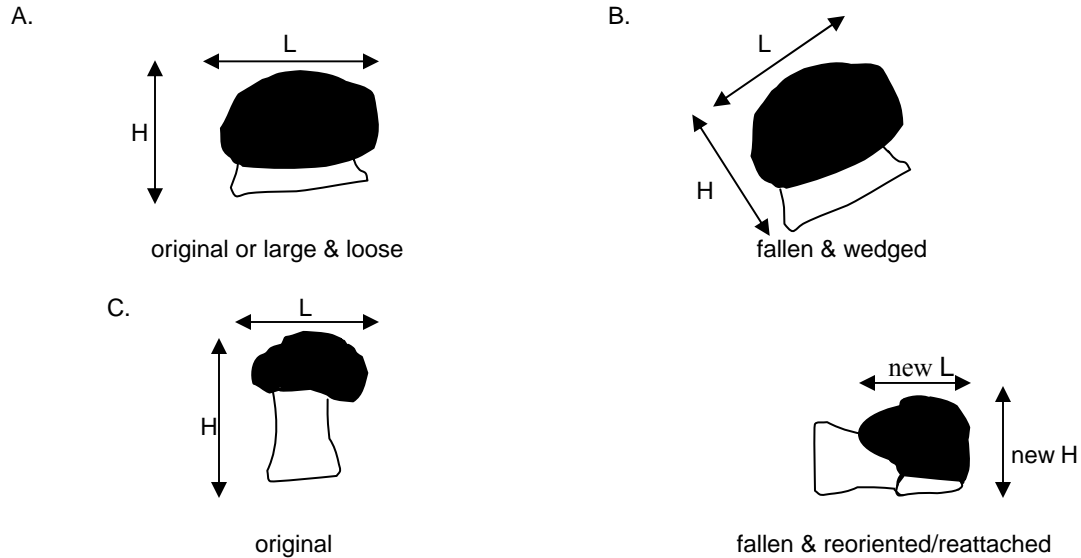


Figure 8. Assessing detached corals. L = length; H = height.

Outward-Facing Surfaces of All Colonies (ignore clumps and fragments)

Detailed-level only: examine the outward-facing surface of each colony in planar view as done above for measuring size. Estimate each of the following to the nearest 5%, unless very small or very large, in which case try to round to the nearest whole number (e.g., 1%, 97%). Can leave blank if 0%:

Bleaching as percent of total (not just live) surface affected. Approximate severity of discoloration as:

% **P** (pale) and/or % **BL** (bleached) (i.e., 30P, 10BL = 30% pale + 10% bleached).

Alternatively, some groups may prefer to qualitatively approximate the severity of any discoloration as:

P (pale) and/or **PB** (partly bleached = patches of fully bleached tissues). or as **BL** (all tissues are fully bleached).

Partial Mortality as % **new**, % **trans** (= **transitional**), and/or % **old**. Although most large colonies have some dead areas, ignore any that are restricted to the sides or bases, and thus not visible when their outward-facing surface is viewed from above.

When corals are partially or completely overgrown by a brown or black, zooxanthellate clionid sponge, the live coral polyps are replaced by sponge tissues with their characteristic ostia and oscules (openings). Even though you may be able to see the coral skeleton beneath the sponge, include the affected area in your estimate of old mortality, and note CZOO OG (=zooxanthellate clionid overgrowth) in the Comments box.

Outward-Facing Surfaces of All Clumps (ignore colonies and fragments)

Detailed-level only: using the 50-cm or 1-m pole for scale, record the condition of the points at 10-cm intervals across the maximum length of each clump as:

L = # live tissues of “normal” pigmentation

P = # pale (live) tissues

BL = # fully bleached (live) tissues

NM = # new mortality

TM = # transitional mortality

OM = # old mortality (includes organisms overgrowing dead parts of the clump)

XX = # points that are not over a part of the clump

(e.g., 9 L, 7 P, 4 TM, 6 OM, 3 XX = 9 live, 7 pale, 4 transitional mortality, and 6 old mortality, for a total of 26 points across the clump and 3 that are not on the clump.)

Entire Surfaces of All Colonies or Clumps (ignore fragments)

Examine the entire colony or clump and note any of the following:

Diseases. If new mortality is common on corals or clumps that are not bleached or broken, and if common corallivores (coral predators) or other known sources of mortality are absent–

Basic-level: put X in the Disease box; identify by disease code if instructed to do so by the team leader.

Detailed-level: identify all common coral diseases and syndromes present in the survey area. Put **UK** (Unknown) when unsure.

Optional: *If unknown, try to get a photograph or describe as follows in the margin of your datasheet: by location (basal, mid, top); presence of one or more foci (= area of active infection); appearance of the interface between remaining live tissues and exposed skeleton (smooth, jagged); if mucus or disintegrating tissues are present; and whether or not adjoining tissues are bleached. Try to match your observations with one of the characterized diseases after the dive.*

Bleaching. Record the presence (**not** percentage) of any conspicuous bleaching as **P** (pale) and/or **PB** (partly bleached), or as **BL** (fully bleached), respectively, as follows–

Basic-level: present **anywhere** on the colony or clump.

Detailed-level: note only if not previously recorded in the Outward-facing Surfaces of Colonies or the Outward-facing Surfaces of Clumps.

Mortality. Record the presence (**not** percentage) of any new, transitional or old mortality as **NM**, **TM** and/or **OM**, respectively, as follows–

Basic-level: present **anywhere** on the colony or clump.

Detailed-level: note only if not previously recorded in the Outward-facing Surfaces of Colonies or the Outward-facing Surfaces of Clumps.

If the colony or clump is entirely dead over its entire surface, record as **SD** (standing dead) providing you can identify it to species (*e.g.*, *Acropora palmata* by gross morphology or *Montastraea cavernosa* by polyp size and shape), or species complex (*e.g.*, *Montastraea annularis* complex or digitate *Porites*), or genus (*e.g.*, *Diploria* by size of meandering ridges and valleys).

Predators. Detailed-level only: if possible note their presence, or clear evidence of activity, as:

PFB = Parrotfish Bites

DFB = Damsel Bites or **DFG** = Damsel Algal Gardens (including any DFB)

CABB = coral-feeding snail, *Corallophilia abbreviata*

HCAR = bristle worm, *Hermodice carunculata*

Major Competitors. Detailed-level only: note only those organisms that have unambiguously killed and/or are overgrowing the live parts of the coral. If you need to create additional codes for locally abundant organisms, write an explanation in the transect comments, *e.g.*, **AKA** = *Aka coralliphaga* (formerly called *Siphonodictyon coralliphagum*).

Unhealthy Looking Tissues. Detailed-level only: if conspicuous, code as **CHC** = Compromised Health in Hard Corals.

6. Periodically check your bottom time and air supply:

If remaining time and available air both permit, after completing the belt on one side of the line, return along the second side, assessing all ≥ 4 cm corals that are at least partially within a 0.5-m wide belt.

Be careful not to resurvey any coral beneath the line that was examined during the first transect.

If at any time during the dive you don't have enough time and/or air left to complete the survey, use any blank spaces remaining on your datasheet to tally (= count and record) by **coral codes** all remaining colonies, clumps or fragments (*e.g.*, **COL:** AAGA ### ## ||, **DSTR** ### |; **CLUMP:** PFUR |; **FRAG** PDIV ||| = 12 colonies of *A. agaricites*, 6 colonies of *D. strigosa*, 1 clump of *P. furcata* and 3 fragments of *P. divaricata*).

This information is important for standardized coral density estimates. Always try to leave enough time to tally all colonies, clumps and fragments present in the belt transect by their species codes.

In high-relief reefs it may be easier to survey both sides of the line at the same time. However, you should still try to spread your assessment along the line in reefs containing too many corals to complete the entire 10 m² survey within one dive.

Optional: Before the dive, you can randomly write the numbers between 0 and 9 on your datasheet to determine the order of surveying the meters along the line.

7. Record the number of m² in which the corals were surveyed and the number of m², if any, in which the corals were tallied by their coral codes.

Other Benthic Organisms

8. If any other group of benthic organisms within your belt transect is conspicuously perturbed by bleaching, disease, predators, etc., record in the transect comments box:
 - its name or AGRRA code
 - its approximate abundance by cover or number
 - the approximate percent or number affected by the perturbation
 (e.g., 10% MALC/90% BL = *M. alcicornis* covers 10% of the substratum, 90% of the colonies are bleached; seafan, 7/20 CYANS = 7/20 *Gorgonia* colonies are being overgrown by cyanobacteria.)

Record any other interesting observations in the Transect Comments box.

9. Free the quadrat end of the line. Wrap the line around the quadrat as you swim towards the other end of the line, then release the loop at the end and tie it to one side of the quadrat.

Check to be sure that you have entered both the area in which all corals were completely surveyed and, if applicable, the area in which they were only tallied by coral codes.

Put the number, and approximate size (as total length), of any lionfishes outside the area of your belt transect in the Site Comments box.

10. After diving, enter all your data and comments on a daily basis into a copy of the appropriate **Basic** or **Detailed CORAL DataEntry-V5.4** spreadsheet. (The Day # and Site # information can help order the UW datasheets.) Be sure to explain any codes of your own invention.

Use a **separate** copy of the spreadsheet for **every site (not every day or every expedition)**, and **check your transcribed data to verify its accuracy**. Back up your own data regularly and store it in a safe place.

11. Once the team leader has signed off on all your spreadsheets, and safely stored the all original UW datasheets, the data are ready to be emailed to data@agrra.org for processing, archiving, and possible posting online at the AGRRA web site.

III AGRRA Fish Surveys (minimum 2 divers)

The visual census of fishes should be located in the same habitat as the benthic and coral transects. Since many fishes are wary of humans, fish transects should be spaced further apart than 5 m whenever possible, and they may need to range into slightly deeper or shallower water. Ideally, fishes should be surveyed between 1000 and 1400 hours when visibility underwater is at a maximum due to overhead sunlight; in reality this is impossible when many sites are sampled throughout the day.

Objectives

- Count and record the size of the AGRRA fishes in the water column above a total of 10, 30-m long × 2-m wide belt transects.
- *Detailed-level only*: measure maximum reef relief at six, regularly spaced intervals along each transect.

New in Version 5

- A. Juvenile scarids (parrotfishes) and haemulids (grunts) are difficult to identify to species without close examination and were omitted from most of the previous AGRRA surveys. Since identification at the family level is more readily learned, they are now included as undifferentiated species groups of < 5 cm parrotfishes and < 5 cm grunts, respectively.
- B. New species in the Version 5 fish list are: (a) potentially significant predators of corallivores (animals that prey on corals) and/or of the key herbivore *Diadema antillarum* (species were chosen on the basis of food items or diet data in FishBase, www.fishbase.org; see also Harborne *et al.*, 2009); (b) moray eels as they can eat ecologically important herbivores (Mumby *et al.*, 2006); and (c) lionfishes (*Pterois* spp.)—invasive Indo-Pacific carnivores that are spreading rapidly throughout the wider Caribbean (Albins and Hixon, 2008; Freshwater *et al.*, 2009; Schofield, 2009).
- C. Maximum reef relief, a proxy for rugosity, is an important component of habitat quality for reef fishes (*e.g.*, McCormick, 1994). It was estimated in the benthic transects during earlier AGRRA surveys, but is more appropriately measured along the fish transects as these cover a much wider area and potentially more variable reef topography.

The amount of time required for the maximum relief measurements will vary according to the rugosity of the substratum and the experience levels of the divers. Three divers may be needed to complete a total of 10 fish transects per dive in very high relief sites.

Unchanged in Version 5

- A. To minimize disturbing the fishes, counts are still made at the same time as the tape is unreeled rather than over a tape after it has been placed on the substratum.
- B. The width of the transect belt remains at 2 m.

Fish data derived from surveys in which the list of species counted, and/or the transect width, length or sampling protocol differ from those employed in the AGRRA project, are not *directly* comparable with the AGRRA data.

Fish identification effort levels

Fish species chosen for AGRRA Version 5 surveys include ecologically important carnivores (many are also commercially significant as food items) and herbivores (which are also eaten in some areas), and fishes that are commercially collected for marine aquaria. A standardized fish list provides divers with a relatively consistent search image that facilitates accurate species identifications and minimizes “observer overload” (K. Marks, pers. obs.). Moreover, line-of-sight issues, which are especially acute in high-rugosity habitats, and errors beyond a diver’s focal range in estimating fish sizes or the location of the belt boundary, are minimized by constraining both the number of assessed species and the transect width (Sale and Sharp, 1983; Floeter *et al.*, 2005; K. Marks, pers. obs.). An inherent limitation of narrow transects, however, is their bias against large schooling, or highly mobile, fishes (Nemeth *et al.*, 2003; Floeter *et al.*, 2005).

Basic: all AGRRA fishes by either the family or species names given in Table 4.

Table 4. Fish families or species and rationale for inclusion in **basic-level** fish surveys.

TAXON	PRIMARY DIET	RATIONALE
BY FAMILY NAME (regardless of species name):		
Acanthuridae (surgeonfishes)	Herbivores ¹	Eat benthic algae
Balistidae (triggerfishes)	Primarily Invertivores	Eat <i>Diadema antillarum</i> + Some are Commercially Significant ²
Chaetodontidae (butterflyfishes)	Primarily Invertivores	Some are Commercially Significant (for aquaria)
Haemulidae (grunts)	Invertivores	Some are Commercially Significant
Kyphosidae (chubs)	Primarily Herbivores	Eat benthic algae
Lutjanidae (snappers)	Piscivores/Invertivores	Commercially Significant + Eat herbivorous fishes
Muraenidae (morays)	Piscivores/Invertivores	Eat herbivorous fishes
Pomacanthidae (angelfishes)	Invertivores/Herbivores	Some are Commercially Significant (for aquaria)
Scaridae (parrotfishes)	Herbivores	Eat benthic algae + Some may eat live corals and either scrape or erode coral skeletons
Serranidae (sea basses) Only Subfamily Epinephelinae (groupers + graysby, red hind, rock hind, coney)	Piscivores/Invertivores	Commercially Significant + Eat herbivorous fishes
BY SPECIES NAME (regardless of family name):		
In Carangidae (jacks), only: <i>Carangoides ruber</i> (bar jack) <i>Trachinotus falcatus</i> (permit)	Invertivores/Piscivores	Commercially Significant + permit may eat <i>Coralliophila</i> spp.
In Diodontidae (porcupinefishes), only: <i>Diodon holocanthus</i> (balloonfish) <i>D. hystrix</i> (porcupinefish)	Invertivores	Eat <i>Diadema</i> ; may eat <i>Coralliophila</i> spp.
In Labridae (wrasses), only: <i>Bodianus rufus</i> (Spanish hogfish) <i>Lachnolaimus maximus</i> (hogfish) <i>Halichoeres bivittatus</i> (slippery dick) <i>H. garnoti</i> (yellowhead wrasse) <i>H. radiatus</i> (puddingwife)	Primarily Invertivores	Commercially Significant + May eat <i>Coralliophila</i> spp. & <i>Diadema</i>
In Monacanthidae (filefishes), only: <i>Aluterus scriptus</i> (scrawled filefish) <i>Cantherhines macrocerus</i> (whitespotted filefish) <i>C. pullus</i> (orangespotted filefish)	Herbivores/Invertivores	Commercially Significant
In Sparidae (porgies), only: <i>Calamus bajonado</i> (jolthead porgy) <i>C. calamus</i> (saucereye porgy) <i>C. penma</i> (sheepshead porgy) <i>C. pennatula</i> (pluma)	Invertivores	Some may eat <i>Diadema</i> or <i>Coralliophila</i> spp.
In other families: <i>Lactophrys bicaudalis</i> (spotted trunkfish) <i>Microspathodon chrysurus</i> (yellowtail damselfish) <i>Sphaeroides spengleri</i> (bandtail pufferfish) <i>Sphyaena barracuda</i> (great barracuda) <i>Pterois</i> spp. (lionfishes)	Invertivore Herbivore Invertivore Piscivore Piscivore/Invertivore	Eat <i>Diadema</i> Eats benthic algae + Commercially Significant (for aquaria) Eat <i>Diadema</i> Commercially Significant + Eats herbivorous fishes Invasive, venomous alien predators + Can be eaten safely after cooking

¹ Herbivores feed mainly or only on plants; Invertivores feed mainly or only on invertebrates; Piscivores feed mainly or only on fishes.

² “Commercially Significant” defined as species in FishBase in 2005 with a Fishery Importance of “Commercial” or “Highly Commercial.”

Detailed: all species in Table 5 and in the **FISH List-V5.4**.

Table 5. Wider Caribbean (WC) species, their diet, and rationale for inclusion in **detailed-level** fish surveys.

TAXON	DIET, TROPHIC LEVEL ²	RATIONALE
ALL WC SPECIES¹:		
Acanthuridae (surgeonfishes)	Herbivores, 2.0	Eat benthic algae
Balistidae (triggerfishes)	Primarily Invertivores, 3.1-3.5; Herbivore/Invertivore: <i>Melichthys niger</i> (black durgon), 2.4	Eat <i>Diadema antillarum</i> : + Commercially Significant: <i>Balistes vetula</i> (queen triggerfish) <i>Canthidermis sufflamen</i> (ocean triggerfish)
Chaetodontidae (butterflyfishes)	Primarily Invertivores, 2.8-3.3	Some Commercially Significant (for aquaria) + Eats coral polyps: <i>Chaetodon striatus</i>
Haemulidae (grunts) score all < 5 cm long by family name only	Invertivores, 3.2-3.5	Commercially Significant: <i>Anisotremus surinamensis</i> (black margate) <i>Haemulon album</i> (white margate) <i>H. flavolineatum</i> (French grunt) + Eats <i>Diadema</i> & may eat <i>Coralliophila</i> spp.: <i>Anisotremus surinamensis</i>
Lutjanidae (snappers)	Piscivores/Invertivores, 3.4-4.5	Commercially Significant + Eat herbivorous fishes
Muraenidae (morays)	Piscivores/Invertivores, 3.9-4.5	Eat herbivorous fishes
Pomacanthidae (angelfishes)	Invertivores/Herbivores, 2.6-3.0	Some Commercially Significant (for aquaria)
Scaridae (parrotfishes) score all < 5 cm long by family name only	Herbivores, 2.0	All eat benthic algae + May eat live corals and either scrape or erode coral skeletons: <i>Scarus guacamaia</i> (rainbow parrotfish) <i>S. vetula</i> (queen parrotfish) <i>Sparisoma viride</i> (stoplight parrotfish)
LISTED SPECIES ONLY:		
In Diodontidae (porcupinefishes), <i>Diodon holocanthus</i> (balloonfish) <i>D. hystrix</i> (porcupinefish)	Invertivores, 3.2-3.4	Eat <i>Diadema</i> ; may eat <i>Coralliophila</i> spp.
In Labridae (wrasses), <i>Bodianus rufus</i> (Spanish hogfish) <i>Lachnolaimus maximus</i> (hogfish) <i>Halichoeres bivittatus</i> (slippery dick) <i>H. garnoti</i> (yellowhead wrasse) <i>H. radiatus</i> (puddingwife)	Primarily Invertivores, 3.3-3.9	Commercially Significant + May eat <i>Coralliophila</i> spp. & <i>Diadema</i>
In Monacanthidae (filefishes), <i>Aluterus scriptus</i> (scrawled filefish) <i>Cantherhines macrocerus</i> (whitespotted filefish) <i>C. pullus</i> (orangespotted filefish)	Herbivores/Invertivores, 2.6-3.0	Commercially Significant

¹ See **Fish List-V5.4** for a complete list of AGRRA fishes.

² Number = Trophic level given in FishBase (www.fishbase.org) for tropical western Atlantic sites in April 2008. Level 1 = photosynthetic organisms (e.g., algae); level 2 = herbivores (primary consumers, e.g., surgeonfish); level 3 = carnivores (secondary consumers, e.g., grunts); level 4 = top carnivores (tertiary consumers, e.g., sharks).

These data are used in the Fish Summary Products to estimate the biomass of AGRRA herbivores, AGRRA invertivores and AGRRA piscivores, respectively.

Table 5, continued.

TAXON	DIET, TROPHIC LEVEL	RATIONALE
LISTED SPECIES ONLY:		
In Serranidae (sea basses), All WC species of <i>Epinephelus</i> , <i>Cephalopholis</i> , <i>Mycteroperca</i>	Piscivores/Invertivores, 3.5-4.5	Commercially Significant + Eat herbivorous fishes
In Sparidae (porgies), <i>Calamus bajonado</i> (jolthead porgy) <i>C. calamus</i> (saucereye porgy) <i>C. penna</i> (sheepshead porgy) <i>C. pennatula</i> (pluma)	Invertivores, 3.2-3.4	Eat <i>Diadema</i> ; may eat <i>Coralliophila</i> spp.: <i>C. bajonado</i> , <i>C. calamus</i> , <i>C. penna</i> May eat <i>Coralliophila</i> : <i>C. pennatula</i>
In other families, <i>Caranx ruber</i> (bar jack) <i>Kyphosus spectator</i> and/or <i>K. incisor</i> (Bermuda & yellow chub) <i>Lactophrys bicaudalis</i> (spotted trunkfish) <i>Microspathodon chrysurus</i> (yellowtail damselfish) <i>Sphoeroides spengleri</i> (bandtail pufferfish) <i>Sphyraena barracuda</i> (great barracuda) <i>Trachinotus falcatus</i> (permit) <i>Pterois</i> spp. (lionfishes)	Invertivore/Piscivore, 3.5-4.5 Herbivores/Invertivores, 2.1 Invertivore, 3.0 Herbivore, 2.1 Invertivore, 3.2 Invertivore/Piscivore, 3.2 Piscivore/Invertivore, 3.7 Piscivore/Invertivore, 4.5	Commercially Significant Eat benthic algae Eat <i>Diadema</i> Eats benthic algae + Commercially Significant (for aquaria) Eat <i>Diadema</i> Commercially Significant + Eats herbivorous fishes May eat <i>Coralliophila</i> spp. + Commercially Significant Invasive, venomous alien predators + Can be eaten safely after cooking

Fish Method

See also the summary/reminder Instructions in the appropriate FISH UW datasheet file.

Begin by choosing the appropriate level (*basic* or *detailed*) of effort for each section of the fish protocol. Before starting to survey, you should conduct **consistency-training exercises** with other fish team members or an instructor to gain practice in setting and retrieving the tape reel, identifying the species of fish that you will survey, and estimating fish sizes underwater. Regardless of the density of fishes at a given site, swim at a speed that will allow you to complete one 30-m transect in about 6 minutes. Don't artificially inflate your abundance estimates by slowing down and waiting for some AGRRA fishes to appear ahead of you on the transect line, by changing your direction of swimming to include any as might be off to one side, or by expanding the width of your transect more than 1 m on each side of the T-bar. **Detailed-level surveys:** also practice measuring maximum relief as you reel in the tape.

Retraining on a weekly basis during expeditions is strongly encouraged.

1A. At each **site**, record the following information on your **Basic** or **Detailed** FISH-UW-V5.4 datasheet before the dive:

Surveyor: 4-letter code with first two letters of your first and last names

Date: Day with two digits/abbreviation of month name/year with two digits (*e.g.*, 14 Aug 07)

Site Name: Local survey site name (if known) or description of area (*e.g.*, off Windy Hill Pt.)

Day #: sequential by day during an expedition (1, 2, 3, etc.)

Site #: sequential within each day (1, 2, 3, etc.)

AGRRA Code: sequential site code, as 3 letters + 2-3 digits (*e.g.*, BAH01, BAH02, BAH03 = first three Bahamian surveys) during an expedition

Latitude & Longitude: as determined by DGPS (or best available instrument) at the site, **to be corrected if necessary from a boat or other fixed position** (see Selecting Survey Sites)

Site Comments: space to describe how latitude and longitude were calculated (*e.g.*, on site or approximated from some fixed position), or other notes about the site—**to be completed by the end of the dive.**

- 1B. Attach a copy of the **FISH List-V5.4** list printed on UW paper to the back of your clipboard if needed for reference.
2. At the survey site, haphazardly choose a starting point for your first transect by swimming around looking for a small crevice in which you can place the weighted end of the tape so it won't drag when the reel stops. Then clip the reel to the D-ring or clamp on your weight belt or BCD to allow the tape to be easily released without having to hold the reel in your hands.

Fishes

3. Write 1 in the **Transect #** box. Record when you start the transect in **Start Time**, plus the **Start Depth** (specify as feet or meters) and, if you can, the **Bottom Temperature** at the depth of the survey habitat. Periodically fixing your eyes on an object in the distance to help you maintain a straight line, release the 30-m tape from the reel while holding the 1-m wide T-bar in front of you. Swim at a steady pace, looking consistently about 2 m ahead of your current position, and giving uniform attention to each successive 2-m segment of the transect.

Estimating the width of the belt with the T-bar, count all AGRRA fishes at the specified (*basic* or *detailed*) level which are located within a belt that is 2-m wide and extends above into the overlying water column. Estimate the total length of each AGRRA fish with the 10-cm increments on the 1-m T-bar, and assign it to one of the following size categories: 0-5 cm; 6-10 cm; 11-20 cm; 21-30 cm; 31-40 cm; > 40 cm. Assess fish schools by mentally partitioning each taxon (species or family) into one or more size categories and approximating the number of individuals in each size class to the nearest 10 if fewer than about 100 fishes, or to the nearest 100 if more than about 100 fishes. Count only those members of a school that happen to be within the 2-m long segment that is immediately in front of you at any given time. Use hash marks when counting small numbers of fishes and whole numbers, separated by commas or with some other delimiting mark (like circling the number), for schools (*e.g.*, ##### ||||, 10, 50 = 69).

You may pause while recording data, and then start swimming again. It is important to swim in a uniform manner. A speed that covers each 30-m transect in about 6 minutes should be attempted, however, high densities of AGRRA fishes could slow this pace.

Briefly describe and sketch any unknown/unfamiliar fish in the margin of the UW datasheet. Body shape and behavior (*e.g.*, swimming with pectoral fins, lying on bottom) may help later to identify its family. Colors and notable markings (spots, lines, etc.) can be essential in determining the species.

Basic-level: AGRRA family and species groups are listed by common English names on the **Basic FISH-UW-V5.4** datasheet.

Detailed-level: frequently encountered species and families are listed by common English names on the **Detailed FISH-UW-V5.4** datasheet. Fill in the name of any unlisted AGRRA species present at the site in the appropriate blank space associated with its family, or in any other blank space on the datasheet.

Stop the fish census when you reach the end of the tape, and start to rewind the tape reel. A method that has worked well while rewinding the transect tape is to unhook the tape reel from the D-ring or clip on your weight belt or BCD and to hold it in front of you while rewinding. As this operation requires both hands, you may find it convenient to rest the horizontal crosspiece of the T-bar in the crooks of your elbows.

Maximum (Max.) Relief

4. **Detailed-level only:** pause at predetermined points (see below) and use your T-bar as a graduated meter stick to delineate a **1-m radius** from the point. Then use your T-bar to measure the vertical height of the tallest coral or reef rock above the lowest point in the underlying substratum. Try to measure Max. Relief to the nearest 5 cm if < 50 cm, and to the nearest 10 cm if > 50 cm high. **Do not use your depth gauge to estimate Max Relief!**

If your tape is marked in meters, make your first measurement at the 30-m mark. As you reel in the tape, pause to measure and record Max. Relief at the 25, 20, 15, 10 and 5-m marks.

If your tape is marked in feet, make your first measurement at the 90 ft mark. As you reel in the tape, pause to measure and record Max. Relief at the 75, 60, 45, 30 and 15-ft marks.

5. After rewinding the tape, record any other interesting observations in the Transect Comments box.
6. Repeat steps 2-5 while trying to stay **at least 5 m** laterally away from your previous position and the other divers, until a total of 10 transects has been completed at the survey site. Be sure to write the **Surveyor, Date, Site Name** and **AGRRA Code at least once on each side of every datasheet**. Put the **Transect #, Start Time** and **Start Depth on all subsequent transects**. Unless you encounter a water mass of a different temperature from that experienced at the first transect, it isn't necessary to continue to record the bottom temperature.
To economize on the use of UW datasheets, one surveyor can be responsible for 4 transects (which requires using both sides of one UW datasheet) and the second can make 6 transects (which requires 1.5 UW datasheets).
7. After diving, enter all your data and comments on a daily basis into a copy of the appropriate **Basic or Detailed FISH-DataEntry-V5.4** spreadsheet. (The Day # and Site # information can help order the UW datasheets.) **Include any species that was identified after the dive on the basis of its UW sketch or description.**

Use a **separate** copy of the spreadsheet for **every site (not every day or every expedition)**, and **check your transcribed data to verify its accuracy**. Back up your own data regularly and store it in a safe place.
8. Once the team leader has signed off on all your spreadsheets, and safely stored all the original UW datasheets, the data are ready to be emailed to data@agrri.org for processing, archiving, and possible posting online at the AGRRA web site.

OPTIONAL COMPONENTS

Several other useful assessments may be integrated into the core protocols if additional information is required locally for certain survey sites. You will need to construct appropriate UW datasheets for some of the methods.

Stony Coral Species Richness

Conduct a roving diver census around the entire habitat and tally all coral species that you can find. (Can be combined with photography or videography of the site and transects.)

Targeted Coral Size and Condition

Additional size, density and condition measurements can be made for any given coral species, or any given coral size class, of interest by increasing the number of haphazardly set, 1 × 10 m belt transects at the survey site.

Targeted Coral Disease(s)

A more reliable estimate of the prevalence of coral diseases can be obtained by increasing the number of haphazardly set, 1 × 10 m belt transects at the survey site.

Targeted Coral Recruitment

A more reliable estimate of coral recruitment can be obtained by increasing the number of haphazardly set, 10-m line transects at the survey site (see Benthic Method, 6A, p. 12).

Reef Fish Species Richness

A roving diver census can be conducted in the same general area as the fish belt transects following the Reef Environmental Education Foundation (REEF) method as briefly explained below. REEF membership is free and any surveyors planning on conducting roving diver censuses should sign-up at www.reef.org.

1. Swim around the reef site for at least 45-60 minutes and record **every fish species** observed on a copy of the REEF UW paper or comparable checklist. Use all your knowledge of fish habits, and be sure to search under overhangs, in any caves, etc.
2. Estimate the **density** of each species by using the following logarithmic categories:
 - Single** = 1 fish
 - Few** = 2-10 fishes
 - Many** = 11-100 fishes
 - Abundant** = >100 fishes
3. Record your observations on a REEF data-entry bubble sheet and mail to REEF or enter the data online using the web-based entry form at www.reef.org.

Herbivory

The effect of herbivorous fishes on macroalgal composition can be approximated with Steneck's (1985) Fish Bite Method. Different guilds of herbivorous fishes are categorized as:

Excavators (Eroders and Scrapers that can remove macroalgal holdfasts while feeding) = parrotfish (scarids);

Denuders (Grazers that eat macroalgal tissues without removing their holdfasts) = surgeonfish (acanthurids), *Microspathodon chrysurus* (yellowtail damselfish);

Non-denuders (Browsers that take bites of macroalgae) = other damselfish (pomacentrids) but not bicolor damselfish (*Stegastes partitus*) which feeds on plankton.

You must be able to distinguish:

Juvenile parrotfishes from juvenile surgeonfishes (acanthurids) and other juvenile fishes with similar stripes, such as wrasses (labrids) or grunts (haemulids) which only look as though they are biting algae as they search for small invertebrates;

Yellowtail damselfish from non-denuding species of damselfish.

1. Use a 1-m pole in conjunction with natural landmarks on the reef surface (*e.g.*, a small coral or gorgonian) to haphazardly delineate an area that is approximately 1 m × 1 m and representative of the benthic cover on the reef substratum.
Do not use a meter quadrat to mark your observation area, as some herbivorous fishes commonly bite novel objects that are placed within their feeding territories.
2. Back off as far as you can while still seeing the meter square area. Watch for 5 minutes. Record the depth, time of day, and number of bites from all species of fishes in the three guilds listed above. Score large (> 20 cm total length) parrotfishes separately from smaller (\leq 20 cm) parrotfishes as they are more effective herbivores. Identify as many of the fishes to species as best as you can.
3. Repeat for a total of at least 5 squares (and 25 minutes observation).
4. Average your counts by guilds or by species; then multiply by 12 to calculate grazing rate/m²/hour.

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