FINAL DRAFT AGRRA METHODOLOGY V. 5.0

Revision by
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EXPLANATION OF CHANGES IN V. 5.0 OF THE PROTOCOLS

Groups are now encouraged to set their own level of survey effort anywhere from ***basic*** (for beginners and some management needs) to ***complete*** (for research). Each group should base its decision on: the project's goals and objectives; the available time or funding for the field work and analysis; any logistical support constraints; and the scuba and taxonomic skills of participants**.**

As in earlier versions of the AGRRA protocols, a minimum of five divers (3 for benthos and 2 for fishes) is needed to complete a survey within one dive. Whenever possible, we urge the inclusion of a sixth diver to make a video and/or photographic record of the benthos transects, other features of the survey site, and for additional safety.

AGRRA Benthos Protocol (3 divers)

The AGRRA benthos protocol is now partitioned into two components in which one diver collects the benthic coverage and abundance data and two divers assess the condition of stony corals. Even though belts now substitute for lines in the stony coral component, transect length remains at 10 m due to the small spatial extent of many reef habitats in the tropical western Atlantic.

AGRRA Benthic Cover/Abundance Survey Objectives

- Count all juvenile and adult *Diadema antillarum* (long-spined urchin) and note the presence of any Caribbean spiny lobster *(Panulirus argus)* or queen conch *(Strombus gigas)* in a 1-m wide belt centered on each of 4-6, weighted line transects.
- Record benthic cover under points at 10-cm intervals under each line transect.

New in V. 5.0

Point counts, each with a corresponding code, have been substituted for the intercept length measurements used in earlier AGRRA surveys in order to increase the ease and speed of data collection. A metric tape attached to a lead-core rope is used to reduce swaying of the tape and maximize comparability with earlier AGRRA surveys.

Point-count effort levels

Basic: Primary reef constructors (stony corals, crustose coralline aglae), and major groups of organisms that kill corals or prevent settlement of coral larvae, are recorded.

CATEGORY	CODE	RATIONALE
Live stony coral	**LC**	Construct coral reefs; universal reef condition indicator
Newly dead stony coral (name only if you can)	**NDC**	Indicates ongoing disease, bleaching, predation or competition
Crustose coralline algae	**CCA**	Construct or cement reef framework; may indicate good conditions for coral recruitment
Macroalgae	**MA**	May inhibit coral larval settlement, overgrow corals, provide refuge for some corallivores, or be a repository for pathogens
Nuisance (conspicuous) cyanobacteria	**CYAN**	Indicate altered reef conditions (possibly nutrients, temperature, low herbivory); may kill/overgrow corals
any ***Aggressive*** Invertebrate	**AINV**	Kill/overgrow corals and crustose coralline algae

Complete: Benthic organisms are grouped primarily by their ecological interactions with stony corals. Many groups (algae, stony corals, other sessile invertebrates) can be surveyed at more than one taxonomic level to accommodate differing programmatic requirements or levels of participant expertise.

CATEGORY	CODE	RATIONALE
STONY CORALS		
Live Scleractinian Coral	**LSC**	Construct coral reefs; universal reef condition indicator along with LMC
Live Milleporan (Fire) Coral	**LMC**	Construct coral reefs; universal reef condition indicator along with LSC
OR stony coral species name (if known)	**CARICOMP code**	As for LSC and LMC
Newly Dead Stony Coral (white skeleton)	**NDSC or NDMC**	Indicates ongoing disease, bleaching, predation or competition
OTHER CALCIFIERS		
Crustose Coralline Algae	**CCA**	Construct or cement reef framework; may indicate good conditions for coral recruitment
OR *Porolithon*	**POR**	As for CCA
Newly Dead Crustose Coralline Algae (orange tissues or white skeleton around green algae)	**NDCCA**	Indicates ongoing disease; outbreaks are reported on some reefs
Calcified Worm Tubes	**CWT**	Potential coral larval settlement site
Peyssonnelid Algae	**PEY**	Calcareous but not a potential coral larval settlement site
MISCELLANEOUS		
Dead coral or pavement ("barren")	**ROCK**	Potential coral larval settlement site
Sand (at least 2.5 cm/1 inch thick)	**SAND**	Not a potential coral larval settlement site; ignore associated epibenthos *(e.g.,* algal turfs, macroalgae)
Rubble	**RUB**	Not a potential coral larval settlement site; ignore associated epibenthos *(e.g.,* algal turfs, macroalgae)
Unknown, invisible (in a hole), sand	**XXX**	Subtract from total as no specific information on how affect corals or their larvae
"ALGAE"		
any conspicuous cyanobacteria	**CYAN**	Indicate altered reef conditions (possibly increased nutrients, temperature, low herbivory);); may kill/overgrow corals
Turf Algae	**TA**	Eaten by many herbivorous fishes when sparse; trap sediment, inhibit coral larval settlement, may kill live corals and crustose coralline algae, and indicate few herbivores when thick
Fleshy Macroalgae	**FMA**	All are eaten by some fishes; some inhibit coral larval settlement or kill corals
OR *Dictyota*	**DIC**	Some experimentally inhibit coral larvae or kill recruits
OR *Lobophora*	**LOB**	Inhibit coral larval settlement; can kill some corals (especially small ones); generally avoided by fishes
OR name of any FMA	**name**	As for FMA
Calcareous Macroalgae	**CMA**	Have chemical defenses against herbivores; may only rarely inhibit coral larval settlement or kill corals
OR *Halimeda*	**HAL**	As for CMA
OR *Halimeda* mat	**HAM**	Inhibit coral larval settlement; probably kill whatever they overgrow; avoided by some fishes; good refuge for some corallivores; may be a repository for pathogens
OR *H. goreauii* mat	**HGM**	As for HAM
OR *H. opuntia* mat	**HOM**	As for HAM
OR name of any CMA	**name**	As for CMA
Mixtures of fleshy & calcareous macroalgae	**FCMA**	Will be scored .5 as FMA and .5 as CMA
OR Names of the algal mixtures	**names**	As for FCMA
INVERTEBRATES		
Aggressive Invertebrates	**AINV**	Invertebrates that kill & overgrow corals and crustose coralline algae
OR *Chondrilla caribensis**	**CHON**	As for AINV
OR red *Cliona delitirx*	**CRED**	As for AINV
OR zooxanthellate (brown or black) clionid	**CZOO**	As for AINV

OR *Briarium asbestinum*	**BRI**	As for AINV
OR *Erythropodium caribaeorum*	**ERY**	As for AINV
OR *Palythoa caribaeorum*	**PAL**	As for AINV
OR *Tridemnum solidum*	**TRI**	As for AINV
OR name any other overgrowing invertebrate	**name**	As for AINV
Other Invertebrates	**OINV**	Epibenthic invertebrates that don't ordinarily kill corals
OR Epibenthic sponge	**SPO**	As for OINV
OR Gorgonian holdfast	**GOR**	As for OINV
OR name of any other OINV	**name**	As for OINV

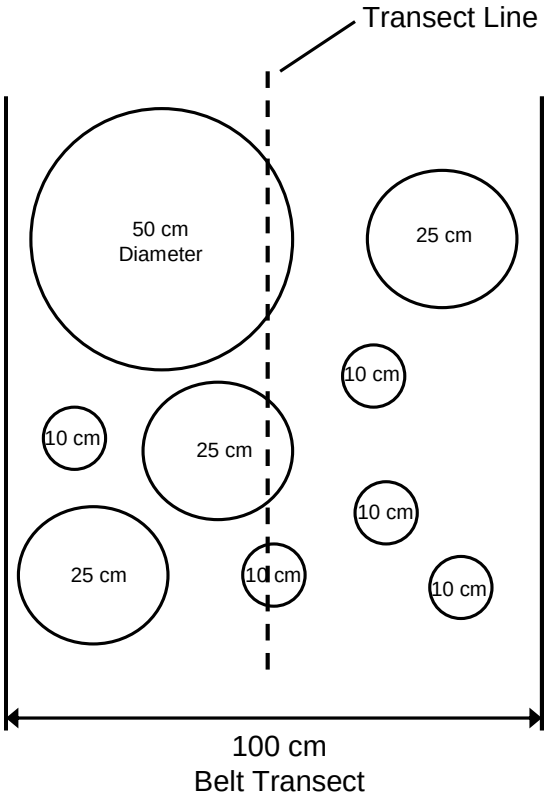
**formerly called Chondrilla nucula*

AGRRA Stony Coral Survey Objectives

- Assess the size and condition of the ≥ 4 cm stony corals (all except *Millepora alcicornis)* in two, 10 x 1-m long belt transects (one diver/transect).

New in V. 5.0

A. Small corals were underrepresented in earlier AGRRA surveys because narrow line transects are biased towards sessile organisms with large diameters (see diagram). Substituting 1-m wide belts, and counting all corals ≥ 4 cm in each of two, 10 x 1 m^2 belts, will allow calculations of population density, size structure, and size-specific condition with the AGRRA V. 5 coral data (Ault and Smith, 2007).



Conceptual diagram of the belt transect versus line-intercept transect methods to illustrate how small size classes of corals are undersampled by line transects due to their low probability of being located beneath a transect line (From Ault and Smith, 2007).

B. Recent mortality as defined in previous AGRRA surveys has been divided into two components, *new mortality* and *transitional mortality* (see **METHODS**[1]). By distinguishing coral tissue death occurring at the time of survey, *new mortality* adds important temporal information during disturbances like outbreaks of disease occurring after mass bleaching events.

C. The number of soft tissue isolates/coral is a new category related to on-going or prior disturbance, and particularly conspicuous after outbreaks of disease or bleaching-related mortality events.

Note: As in Version 4, of the benthos protocol, coral width is defined as the maximum distance orthogonal to maximum length (=maximum diameter in Versions 1-3 of the AGRRA benthos protocol).

Estimates of partial mortality in assessments that include the entire coral are not directly comparable with the AGRRA data. Partial mortality is still restricted to the outward-facing coral surfaces in the AGRRA protocols for reasons of greater simplicity, speed and estimation accuracy (J. Lang, pers. obs.).

Stony-coral effort levels
Basic: Divers must be able to identify to species the stony corals found in the surveyed habitats, measure coral size, assess partial mortality, and check for signs of bleaching and disease.

Complete: Divers record other perturbations such as predation or overgrowth by organisms, and count any damselfish with algal gardens within the belt transect.

AGRRA Fish Protocol (2 divers)

Belt transects remain the core of the fish protocol. Roving diver surveys are now an optional component.

AGRRA Fish Survey Objectives
- Count and record the size of all AGRRA fishes in 10, 30 x 2-m long belt transects.
- Measure maximum reef relief at regularly spaced intervals along each transect.

New in V. 5.0
A. Important predators of stony corals (corallivores) and of the key herbivore *Diadema antillarum,* plus invasive, Indo-Pacific lionfishes *(Pterois* spp.) have been added to V. 5 of the AGRRA fish list.

B. Juvenile parrotfishes (scarids) and grunts (haemulids), which are difficult to identify to species without close examination, were omitted from earlier AGRRA surveys. Since identification at the family level is readily learned, however, they are now included as groups of < 5 cm parrots and < 5 cm grunts, respectively.

C. Maximum reef relief (MRR, a proxy for rugosity) is an important component of habitat quality for reef fishes. MRR was estimated in the benthic transects during earlier AGRRA surveys, but is more appropriately measured along the fish transects which cover a much wider area and potentially more variable reef topography.

Note: Fish data derived from surveys in which the list of species counted, and/or the width or length of the belt transects *(e.g.,* Sale and Sharp, 1983), differ from that employed in the AGRRA fish protocol are not directly comparable with the AGRRA data. Constraining the AGRRA species list to commercially significant or ecologically important fishes, and the width of the AGRRA belt transect to 2 m, minimizes

[1] link in online version to section 5 d of the Stony Coral Survey method

"observer overload," line-of-sight issues (which are especially acute in high-rugosity habitats), and errors in estimating fish sizes or the location of the belt boundary (K. Marks, pers. obs.). Belt transect length was previously standardized at 30 m to minimize incidental coverage of non-reefal habitats *(e.g.,* sand, sea grass meadows).

Fish-identification effort levels

Basic: Commercially significant grunts, snappers and groupers, ecologically important parrotfishes and surgeonfishes, several other easily recognized species and, in some locations, invasive Indo-Pacific lionfishes; indicated by bold type in the following table.

***Complete*:** All species in the following table.

Version 5 Fishes, their Diet and Rationale for inclusion in AGRRA fish surveys.

FAMILY SPECIES	DIET	RATIONALE
Acanthuridae (surgeonfish) **all tropical western Atlantic (TWA) species**	Denuding[2] Herbivores/ Invertivores, 2.0[3]	Eat benthic algae
Balistidae (triggerfish, also called leatherjacket) all TWA species	Invertivores, 3.1-3.5 Herbivore/ Invertivore*:* *Melichthys niger* (black durgon), 2.4	All eat *Diadema antillarum:* *Balistes vetula* (queen triggerfish), 3.4 + Commercially Significant*:* *Canthidermis sufflamen* (ocean triggerfish), 3.2-3.5
Chaetodontidae (butterflyfish) **all TWA species**	Primarily Invertivores, 2.8-3.3	Some sold live for aquaria + Eats coral polyps: *Chaetodon striatus*, 3.2
Diodontidae (porcupinefish) *Diodon holocanthus* (balloonfish) *D. hystrix* (porcupinefish)	 Invertivore, 3.3-3.4 Invertivore, 3.2-3.4	 May eat *Coralliophila* spp. & *Diadema* May eat *Coralliophila* spp. & *Diadema*
Haemulidae (grunt) **all TWA species; score all <5 cm long by family (as grunts) only**	Invertivores, 3.2-3.5	"Commercially Significant"[4] Species*:* *Anisotremus surinamensis* (black margate), 3.3 *Haemulon album* (white margate), 3.2 *H. flavolineatum* (French grunt), 3.3 Eats *Diadema*; May eat *Coralliophila* spp. *Anisotremus surinamensis* (black margate), 3.3
Labridae (wrasse) ***Bodianus rufus* (Spanish hogfish)** ***Lachnolaimus maximus* (hogfish)** *Halichoeres bivittatus* (slippery Dick) *H. garnoti* (yellowhead wrasse) *H. radiatus* (puddingwife)	 Invertivore, 3.4 Invertivore, 3.3-3.9 Invertivore/Piscivore, 3.3-3.6 Invertivore, 3.5 Invertivore, 3.3	 May eat *Coralliophila* spp. & *Diadema* May eat *Coralliophila* spp. & *Diadema* May eat *Coralliophila* spp. & *Diadema* May eat *Coralliophila* spp. & *Diadema* May eat *Coralliophila* spp. & *Diadema*
Lutjanidae (snapper) **all TWA species**	Piscivores/Invertivores, 3.4-4.5	"Commercially Significant" Species*:* *Lutjanus analis* (mutton snapper), 3.8-3.9 *L. apodus* (schoolmaster), 3.5-4.4 *L. cyanopterus* (cubera snapper), 4.2-4.5 *L. griseus* (grey snapper), 3.6-4.3 *L. jocu* (dog snapper), 3.4

[2] Denuding = browsers that can significantly reduce algal turfs and fleshy macroalgal biomass when in high densities *(e.g.,* Steneck, 1988)

[3] Number = trophic level given for TWA sites as given in FishBase in April 2008.

[4] "Commercially Significant" defined as species in FishBase in 2005 with Fishery Importance of Commercial or Highly Commercial.

		L. mahogoni (mahonany snapper), 4.4 *L. synagris* (lane snapper), 3.7-4.3 *Ocyurus chrysurus* (yellowtail snapper), 3.5-4.4
Monacanthidae (filefish, also called leatherjacket) *Aluterus scriptus* (scrawled filefish) *Cantherhines macrocerus* (whitespotted filefish) *C. pullus* (orangespotted filefish)	 Herbivore/Invertivore, 2.8 Invertivore/Herbivore, 3.0 Herbivore/Invertivore, 2.6	<u>May eat juvenile *Diadema*</u>
Pomacanthidae (angelfish) **all TWA species**	InvertivoresHerbivores, 2.6-3.0	<u>Some are collected for aquaria</u>
Scaridae (parrotfish) **all TWA species, score all <5 cm long by family (as parrots) only**	Herbivores, 2.0 Excavating[5]: *Scarus* spp., *Sparisoma viride* (stoplight parrotfish) Denuding: Many *Sparisoma* spp.	<u>Eat benthic algae,</u> <u>+ May graze live corals:</u> *Scarus guacamaia* (rainbow parrotfish), 2.0 *S. vetula* (queen parrotfish), 2.0 *Sparisoma viride* (stoplight parrotfish), 2.0
Serranidae (groupers and seabasses) ***Cephalopholis*–all TWA species** ***Epinephelus*–all TWA species** ***Mycteroperca*–all TWA species**	Piscivores/Invertivores, 3.5-4.5	<u>"Commercially Significant" Species:</u> *Cephalophis fulvus* (coney), 4.1 *Epinephelus adscensionis* (rock hind), 3.5 *E. guttatus* (red hind), 3.9 *E. marginatus* (dusky grouper, Brazil) *E. morio* (red grouper), 3.5-3.7 *E. striatus* (Nassau grouper), 3.1-4.4 *Mycteroperca bonaci* (black grouper), 4.5 *M. microlepis* (gag), 3.7 *M. phenax* (scamp), 4.5 *M. tigris* (tiger grouper), 4.5 *M. venenosa* (yellowfin grouper), 4.4-4.5
Sparidae (porgy) *Calamus bajonado* (jolthead porgy) *C. calamus* (saucereye porgy) *Calamus penna* (sheepshead porgy) *C. pennatula* (pluma)	Invertivores: 3.2 3.3 3.4 3.3	 Eat *Diadema;* May eat *Coralliophila* spp. Eat *Diadema;* May eat *Coralliophila* spp. Eat *Diadema;* May eat *Coralliophila* spp. May eat *Coralliophila*
Species in other families ***Caranx ruber* (bar jack)**	Invertivore/Piscivore, 3.5-4.5	"Commercially Significant"
***Kyphosus sectactrix and/or K. incisor* (Bermuda & yellow chub)**	Denuding Herbivore /Invertivore, 2.0	Eat benthic algae
***Microspathodon chrysurus* (yellowtail damselfish)**	Denuding Herbivore/ Invertivore, 2.1	Eats benthic algae
***Sphyraena barracuda* (barracuda)**	Piscivore/Invertivore, 4.5	May become common when "Commercially Significant" species are overfished; eaten where no ciguatera?
Trachinotus falcatus (permit)	Invertivore/Piscivore, 3.2	May eat *Coralliophila* spp.
***Pterois* (lionfishes)** **OR *Pterois miles* (devil lionfish)** **OR *P.volitans* (red lionfish)**	Invertivores/ Piscivores	Invasive, venomous aliens As for *Pterois* As for *Pterois*

References

Ault, J.S., and S.G. Smith. 2007. Statistical sampling design analysis of the AGRRA Caribbean coral (benthos) database. University of Miami, Florida. Final Report to the NOAA Coral Reef Conservation Program. 35 p.

[5]Excavating = grazers that can consume the toughest algae like crustose coralline algae (after Steneck 1988); further partitioned in the TWA by Bruggemann et al. (1996) into shallow scrapers like *Scarus vetula* (queen parrotfish), *Scarus taeniopteris* (princess parrotfish), *Scarus iseri* (striped parrotfish) and deep excavators like *Sparisoma viride.*

Bruggemann, J.H., A.M. van Kessel, J.M. van Rooij, A.M. Breeman. 1996. Bioerosion and sediment ingestion by the Caribbean parrotfish *Scarus vetula* and *Sparisoma viride:* implications of fish size, feeding mode and habitat use. Mar. Ecol. Progr. Ser. 134:59-71.

Sale, P.F. and B.J. Sharp. 1983. Correction for bias in visual transect censuses of coral reef fishes. Coral Reefs 2:37-42.

Steneck, R.S. 1988. Herbivory on coral reefs: a synthesis. Proc. 6th Int. Coral Reef Symp. I:37-49.

SELECTING SURVEY SITES

An AGRRA **site** is situated in a geomorphological **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 (**Spalding et al, 2007).

A site is defined as a more or less homogeneous habitat, roughly 200 m x 200 m in spatial extent, and accessible from a boat or by swimming from shore. A common goal during AGRRA expeditions is to characterize reef condition in zones of maximum reef development at sites that would be considered representative of a particular location–such as a shelf, an island or a country. 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 datasheets and Excel spreadsheets.

If the spatial extent, habitat complexity, and/or number of reefs in the study location 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 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, nearshore fringing reefs, lagoonal or mid-shelf patch reefs), orientation *(e.g.,* windward or leeward exposure), depth, slope, etc. Reef crests dominated by *Acropora palmata* (about <1-5 m) and fore reefs with the *Montastraea annularis* species complex or other massive corals (about 8-15 m) are among most ubiquitous and important habitats in many Caribbean reefs, and highly recommended for AGRRA surveys. (Given its threatened status in the western Atlantic, information on *Acropora palmata* is particularly important nowadays–even when most of the colonies are dead and/or their borders are unclear, in which case point counts can substitute for individual coral assessments as described in the **stony coral survey**[6] section of **METHODS.**

If these two habitats are locally absent, rare, or physically inaccessible, other habitats that are dominated by reef-building corals should be chosen instead for survey. Try to avoid hard-grounds, pavements, etc., 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 assess. 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 x 200 m squares superimposed over the reef in a map, remote image or GIS product 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, 2005) or 2-stage stratified random sampling (Cochran, W.G. 1977).

The minimum number of randomly chosen sites to survey in each habitat will increase as the area of the study location increases *(e.g.,* S. Cuba > N. Jamaica > Bonaire). The table below approximates minimum numbers for selected shelves in the Tropical Northwestern Atlantic, using estimated reef areas provided by The Nature Conservancy that are based on the Millennium Coral Reef Mapping Project's geomorphic reef classification (see http://imars.usf.edu/corals/). Note that reef habitats have been lumped together for

[6] link in online version to Section 5 f ***How to assess large clusters***….of the stony coral survey method

this analysis. For areas in which the reefs are not visible in the Millennium Maps (mostly narrow, inshore fringing reefs), a minimum of five sites should be sampled within each chosen habitat stratum.

Unless you are sure that the habitat to be surveyed is present on each selected reef, we recommend having several alternative, randomly chosen sites in case some in the initial selection are found to be unsuitable (e.g., the habitat was misclassified, or it proves to too dangerous to survey due to inclement weather).

Minimum target sample size projections (# of sites) for selected AGRRA Caribbean shelf units on reef areas calculated from Millennium reef maps (from G.A. Ault and S.G. Smith, pers. comm.).

Shelf Unit	Target # of sites	Shelf Unit	Target # of sites
Grand Bahama Shelf	58	South Central Cuba Shelf	10
Abaco Shelf	82	SE Cuba Shelf	301
Berry Islands Shelf	18	Little Cayman Shelf	10
Bimini Shelf	12	Grand Cayman Shelf	12
Cay Sal Bank	39	North Jamaica Shelf	37
Andros Shelf	43	South Jamaica Shelf	44
New Providence Shelf	18	Pedro Bank Shelf	33
Exumas Eleuthera Shelf	155	East Jamaica Shelf	35
Long Island Shelf	27	Morant Cays Shelf	10
Southern Great Bahama Shelf	35	South Haiti Shelf	30
East Bahama Shelf	13	West Haiti Shelf	40
East Acklins Shelf	10	North Hispanola Shelf	47
Acklins Crooked Shelf	18	NE DR Shelf	26
East Crooked Shelf	10	East DR Shelf	21
Little Inagua Shelf	16	South Hispanola Shelf	14
North Inagua Shelf	10	North Puerto Rico Shelf	26
Great Inagua Shelf	22	South Puerto Rico Shelf	27
Grand Turk Shelf	41	USVI BVI Shelf	43
East Caicos Shelf	10	St Croix Shelf	13
East Cuba Shelf	69	Anguilla Shelf	14
North Cuba Shelf-1	56	Saba Shelf	16
North Cuba Shelf-2	19	Antigua Shelf	13
NW Cuba Shelf	78	Montserrat Shelf	5
SW Cuba Shelf	15	Guadeloupe Shelf	28
Isle of Youth Shelf	87	Dominica Shelf	10

Alternatively, it may be necessary to survey sites that are chosen ***strategically*** for some special purpose *(e.g.,* considered degraded, threatened, or in particularly good condition; located within an MPA or fishing area, or off every headland or village), or at some predetermined distance (*e.g.,* 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.

It is critical that the exact location of the actual site be recorded using 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 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.

References:

Cochran, WG. 1977. *Sampling Techniques*. 3rd edition. John Wiley, NY, 428 p.

Spalding, MD, HE Fox, GR Allen, N Davidson, ZA Ferdaña, M Finlayson, BS Halpern, MA Jorge, A Lombanam SA Lourie, KD Martin, E McManus, J Molnar, CA Recchia and J Robertson. 2007. Marine ecoregions of the World: a bioregionalization of coastal and shelf areas. *Bioscience* 57:573-583.

Stevens, D L, and AR Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99: 262-278

Sullivan, K, and G Bustemante. 1999. *Setting Geographic Priorities for Marine Conservation in Latin America and the Caribbean*. Arlington, VA. The Nature Conservancy

EQUIPMENT

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

- a clipboard or underwater (UW) slate (see below) and pencils
  Attach at least one pencil to the clipboard or your wrist with a series of interconnected rubber bands; carry a spare somewhere secure.
- UW datasheets (see below), with rubber bands or clips to fasten to the clipboard or slate
  See the pdfs of the datasheet templates that can be photocopied with a laser printer onto both sides of underwater "DuraCopy" Copier/Laser Paper 6511. Although expensive (about US $65.00 for 100, 8 1/2" x 11" sheets in Spring 2008 from online distributors), this paper is highly recommended. Your data are more likely to be entered correctly because the appropriate template is present on every datasheet.
- Perhaps glasses or contact lenses
  If you normally wear them on land, it is important to have a diving mask with the correct prescription lenses or wear your contacts on the dive. Otherwise you may not be able to distinguish some important details while doing the surveys.

Benthic Cover/Abundance Survey divers will need:

- a *letter-sized* clipboard or UW slate and pencils
- copies of the PointCount-UW-V5.0 datasheet
- a 10-m long, "weighted tape" (metric tape attached to lead-core rope)
  Carefully cable-tie a 10-m length of tape marked in metric units to a .25" diameter lead-core rope (available at commercial fishing supply stores or cooperatives). Attach a tie-off line at the 0-m end and a hook attached to a tie-off line at the 10-m end. See photo below.
- a 1-m long measuring pole marked in 10-cm intervals
  Use .5" diameter PVC pipe (available at hardware stores). Paint a scale along the pipes showing 10-cm increments. See instructions and photo below.
- a small, thin, metric, plastic ruler, trimmed to have a tapered point but still be legible at its basal 5 cm
  Drill or punch a hole at the 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 x 25 cm PVC (or equivalent) quadrat
  For convenience in swimming, hook the 10-m end of weighted tape to the quadrat, wrap the tape tightly around the quadrat and attach the 0-m tie-off with a loop. Insert the pole and clipboard through the center between the wrapped tape. See photos belows.

Stony Coral Survey divers will need:

- a *letter-sized* clipboard UW slate and pencils
- copies of the CoralBelt-UW-V5.0 datasheet
- a 10-m long lead-core transect line marked at 1-m intervals (with colorful cables-ties, electrical tape or permanent ink), and with tie-off lines at both ends; can have a hook at one end
- a 1-m long measuring pole marked in 10-cm intervals
- a 50-cm long measuring pole marked in 10-cm intervals, with 5-cm increments at each end
  Use .5" diameter PVC pipes (available at hardware stores) for both poles. Paint a scale along the pipes showing 10-cm increments. See instructions and photo below.
- a 25 cm x 25 cm PVC (or equivalent) quadrat
  For convenience in swimming, tie or hook one end of weighted line to the quadrat, wrap the line tightly around the quadrat and attach other tie-off with a loop. Insert the pole and clipboard through the center between the wrapped line. See photos below.

Insert construction instructions & photos here

Fish Survey divers will need:

- a 6" x 9" UW slate *(e.g.,* a REEF slate, see below) with copies of the FISH-UW-V5.0 datasheet

The slate can be mounted on the T-bar to facilitate carrying the equipment. See photos below.

- a weighted, 30-m/100-ft, fiberglass transect tape

  Attach a 2-3 lb weight at the free end of the tape and a clip on the reel to attach the tape reel to a D-ring on your BCD or weight belt.

- 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 .75" diameter PVC pipe and a T connector (available at hardware stores). Paint a scale along the arms showing 10-cm increments. See photos below.

Insert construction instructions & photos here

METHODS

Begin by choosing the appropriate level (from ***Basic*** to ***Complete***[7]*)* of survey effort for each section of the protocol.

A. AGRRA Benthic Cover/Abundance Survey (1 diver)

Before starting to survey, you should conduct **consistency-training exercises** with other benthos team members or an instructor to gain practice in setting and retrieving the weighted transect line (tape/lead-core rope), in locating points on the substratum, assigning them to the AGRRA point-count categories chosen for inclusion in your surveys, and learning their corresponding codes. **Retraining on a weekly basis during expeditions is strongly encouraged.**

1. At each **site**, record the following information on your UW **BENTHIC** datasheet before the dive:
   Recorder: 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 generic description of location
   Day #: sequential, if during an expedition (1, 2, 3, etc.)
   Site #: sequential each day (1, 2, 3, etc.)
   Latitude & Longitude as determined by DGPS (or best available instrument) at the site, **corrected if necessary from a boat or other fixed position**[8]
   AGRRA Location Code: sequential as a 3 letter + 2-3 digit code *(e.g.,* BAH01, BAH02, BAH03, etc.)
   Reef Type: *(e.g.,* bank, barrier, mid-shelf, fringing).
   If different from expected, please describe the reef type surveyed.
   Reef Zone: *(e.g.,* back reef, reef crest, fore reef, bank crest)
   If different from expected, please describe the reef zone surveyed.
   Subzone/habitat: *(e.g.,* breaker/*palmata,* low-relief/massive corals, spur and groove/*Montastraea)*
   If different from expected, please describe the habitat surveyed.
   Selection Method: *(e.g.,* stratified random, stratified strategic)
   Comments: space to describe how latitude and longitude were calculated *(e.g.,* on site or approximated from a different fixed position) or other qualifying remarks

2. At the survey site, use a haphazard method to choose a starting point for your first transect *(e.g.,* by spinning several times with your eyes closed or gently dropping your meter pole while descending–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**. Tie the free end of the weighted tape to a dead piece of coral or other secure object that wouldn't easily be damaged. Note the **Start Depth** at the 0-m mark, and circle whether your depth gauge is recording in feet (ft) or meters (m). Without biasing your choice of direction by looking down, unwind the tape from the quadrat as you swim away from this starting point.
   Be sure to avoid, and don't cross, benthic transects that are being set by other divers. Try to stay away from the edges of the reef unless directed to survey in this habitat type, and to avoid areas with abrupt changes in slope, deep grooves, large patches of sand or unconsolidated coral rubble. Unusual reef features should only be included to the extent appropriate to their relative abundance at the site.
   At the end (past the 10-m mark), pull tightly to ensure the weighted tape is taut, and secure to the bottom by wrapping the quadrat around or over some non-fragile object. Note the **End Depth** at the

[7] link in online version to first paragraph of **CHANGES IN VERSION V.5**

[8] link in online version to last paragraph of **SELECTING SURVEY SITES**

10-m mark.

4. As you return towards the starting point, you may need to straighten the tape by repositioning one of its ends, or pull it off the bottom in high-relief reefs, or disentangle 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 its specific location during your survey! Please also note its presence and approximate size in the Comments box at the top of your datasheet.*

5. Using the 1-m measuring pole perpendicular to the line transect for horizontal scale, swim a 0.5-m wide belt transect along one side of the weighted tape. Ignoring all other species of sea urchins, tally (count and record) every "juvenile" and "adult" long-spined urchin *(Diadema antillarum)* that you see between the 0- and 10- m marks. If you see any Caribbean spiny lobster *(Panulirus argus)* or queen conch *(Strombus gigas)*, circle Y (Yes) in the appropriate box.

   Inspect all shelter-providing spaces (e.g., crevices, bases of large corals) within the belt. Score Diadema with black-and-white banded spines as juveniles, and those either with all-black spines or with all-black alternating with all-white spines as adults. 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.

   If the line sways due to strong surge or bottom current, note its position in the middle of its swing when positioning the pole.

6. Return to the 0-m position by swimming a second, 0.5-m wide belt transect along the other side of the tape. Tally all juvenile and adult *Diadema*. Continue looking for *P. argus* and *S. gigas*, or circle N (No) if none are seen in the two belt transects.

7. Starting at the 0-m mark, swim back above the weighted tape, recording what is immediately below on the substratum at 10-cm intervals (ending at the 9-m, 90-cm point) with the category codes listed at the base of your UW datasheet.

   Excluding crustose corallines, measure the height of the algae in each group, genus, or species being surveyed with the tapered ruler to the nearest .5 cm (if < 1 cm tall) or the nearest cm (if > 1 cm tall). Record as name/height, as in MA/3 (= macroalgae, 3 cm tall).

   As soon as you are familiar with the normal height any of particular algal category in each transect (or even site), you can stop recording this height and thereafter only note unusual departures from the average–providing you remember to include the average height for ***each*** entry when transcribing your data in the PointCount Spreadsheet.

   If you need to create additional codes for locally abundant organisms, write an explanation in the Transect comments row *[e.g.,* MIC = *Microdictyon;* CVAR = *Cliona* (formerly *Anthosigmella) varians]*.

   If the reef has high relief, and you are unable to locate the position of the point(s) to count on the bottom 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 wide expanse of sand or pavement, note on your UW datasheet which intervals are involved *(e.g.,* from 4.5 - 5.3 m), then place the measuring pole on the bottom under the tape and record what is immediately beneath its 10-cm marks across this interval.

     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 (and any algal heights) 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 you are uncertain of their identity, scratch the surfaces of calcareous crustose algae with a sharp instrument: crustose corallines have white skeletons and peyssonnelid skeletons are dark.

8. When the point counts are complete, pick up the quadrat and wrap the weighted tape around it as you swim to the 0-m end and release its tie-off line.

9. Repeat steps 2-8 for **3-5** additional transects, being sure to stay at least 5 m away from your previous locations and the two stony coral transects. After completing the last transect and rewinding the weighted tape, reattach the 0-m tie off to the quadrat.

   If macroalgae, or any other category apart from stony corals, collectively occupy 50% or more of the substratum at the site, this category can be ignored after the 3rd transect-but be sure to note as much in the remaining Transect comments rows.

10. After diving: enter your data, including comments, on a daily basis into the **Benthic** sheet of an AGRRAspreadsheetV5.0.xls. Remember to provide a height estimate for every algal entry (see 7 above). Be sure to include a list describing any additional acronyms created during the survey. Remember to use a **separate** copy of the spreadsheet for **every site**, 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 your spreadsheets, and safely stored the original UW datasheets, the data are ready to be emailed to:
    data@agrra.org

Optional Additions at Step 8:
Use the margin of the your datasheet or a blank sheet of UW paper to record this information.
Large coral census
8A. Pause at any "large" *(i.e.,* at least 1 m wide and/or 1 m tall) stony coral underlying the line. Record its identity; measure its **maximum length**, **maximum width,** and **maximum height**[9].

Coral Recruitment and SubstratumType
8B. After finishing the point counts, temporarily unhook the quadrat, and attach the 10-m tie-off line to the bottom.

8C. Re-swim the transect, placing the 25 x 25 cm quadrat every two meters directly below the meter mark on the line. Tally the number of small (up to **2 cm** maximum diameter) stony corals (including any *Millepora)* in the quadrat. Identify any as you can to the genus or species level. If the quadrat lands on a section of high topographical complexity search all substrata as you can see regardless of their orientation relative to the quadrat's planar surface (after Slingsby and Steneck, in review).
Practice and good eyesight (or corrective lenses) are need to be successful in finding small corals due to their inconspicuous size.

Also record the predominant substratum type within the quadrat as pavement (pv), live coral (lc), dead coral (dc), rubble (rb) or sand (sn).

3. Return to the 10-m end and rehook the quadrat to the tie-off line.

[9] link in online version to section 5b of the Stony Coral Survey method

B. AGRRA Stony Coral Survey (2 divers)

Before starting to survey, you should conduct **consistency-training exercises** with other benthos team members or an instructor to gain practice in setting and retrieving the weighted transect line (lead-core rope), in determining stony coral boundaries, measuring their sizes, and estimating % partial mortality. You may also need to learn to recognize tissue isolates, signs of disease, bleaching, predation and competition in stony corals, and the AGRRA codes for these perturbations. **Retraining on a weekly basis during expeditions is strongly encouraged.**

1. At each **site**, record the following information on your UW **CORAL** datasheet before the dive:
   Recorder: 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 generic description of location
   Day #: sequential, if during an expedition (1, 2, 3, etc.)
   Site #: sequential each day (1, 2, 3, etc.)
   Latitude & Longitude as determined by DGPS (or best available instrument) at the site, **corrected if necessary from a boat or other fixed position**[4]
   AGRRA Location Code: sequential as a 3 letter + 2-3 digit code *(e.g.,* BAH01, BAH02, BAH03, etc.)
   Reef Type: *(e.g.,* bank, barrier, mid-shelf, fringing).
   If different from expected, please describe the reef type surveyed.
   Reef Zone: *(e.g.,* back reef, reef crest, fore reef, bank crest)
   If different from expected, please describe the reef zone surveyed.
   Subzone/habitat: *(e.g.,* breaker/*palmata,* low-relief/massive corals, spur and groove/*Montastraea)*
   If different from expected, please describe the habitat surveyed.
   Selection Method: *(e.g.,* stratified random, stratified strategic)
   Comments: space to describe how latitude and longitude were calculated *(e.g.,* on site or approximated from a different fixed position) or other qualifying remarks

2. At the survey site, use a haphazard method to choose a starting point for your first transect *(e.g.,* by spinning several times with your eyes closed or gently dropping your meter pole while descending–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**. Tie the free end of the weighted line to a dead piece of coral or other secure object that wouldn't easily be damaged. Note the **Start Depth** at the 0-m mark, and circle whether your depth gauge is recording in feet (ft) or meters (m). Without biasing your choice of direction by looking down, unwind the line from the quadrat as you swim away from this starting point.
   Be sure to avoid, and don't cross, benthic transects that are being set by other divers. Try to stay away from the edges of the reef unless directed to survey in this habitat type, and to avoid areas with abrupt changes in slope, deep grooves, large patches of sand or unconsolidated coral rubble. Unusual reef features should only be included to the extent appropriate to their relative abundance at the site.
   At the end (past the 10-m mark), pull tightly to ensure the weighted line is taut, and secure to the bottom by wrapping the quadrat around or over some non-fragile 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, or pull it off the bottom in high-relief reefs, or disentangle 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! Please also note its presence and approximate size in the Comments box at the top of your datasheet.*

5. Using the 1-m measuring pole perpendicular to the transect line for horizontal scale, swim a 0.5-m wide belt transect along one side of the weighted line. Examine each stony coral (all scleractinians and *Millepora,* excepting *M. alcicornis)* that is ≥ 4 cm in maximum length and either under the line or for which at least 50% of its surface area lies within the belt.
   Ignore all corals that are < 4 cm in maximum length, and all that are > 50% outside the belt unless they are under the line and >1 m in maximum length.

   a. Identify each coral species using its 4-letter CARICOMP code. Include all entirely dead corals that can be identified at least to genus and are still mostly intact *(i.e.,* ignore dead branching corals that have lost most of their branches as their size estimate will be grossly inaccurate).
      CARICOMP stony coral codes are based on the first letter of the genus name followed by the first three letters of the corresponding species name, e.g., Diploria strigosa = DSTR, Porites astreoides = PAST. You can attach a copy of the coral code file printed on UW paper to one side of your clipboard if needed for reference.

   b. Measure the **maximum length**[10] and the **maximum width**[6] of the outward-facing coral 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 .5-m pole for smaller corals, and the 1-m pole for large colonies. Try to record these measurements to the nearest 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 the coral have died and are overgrown by other organisms–particularly other corals of the same species. Look for connected live tissues, basal skeletal connections, or at the size and color of separated tissue isolates.

   c. Count and record the number of soft tissue isolates in the coral. (If >10, estimate to the nearest 5 as 15, 20, 25, 30, etc.)

   d. Estimate the partial mortality, if any, of the coral surface from a planar view perpendicular to its axis of growth. Try to round your percentage to the nearest 5% unless it is very small or very large, in which case try to round to the nearest whole number (e.g., 1%, 97%). Although most colonies have some dead areas, 0% is recorded whenever these are restricted to the sides or bases and not visible when their outward-facing colony surface is viewed from above.

      Recent mortality as originally defined in the AGRRA benthos protocol is now partitioned as:
      New mortality–(% New Mortality on the UW Datasheet)–non-living part(s) of the coral in which the corallite structures are still intact and the freshly exposed, white surface is free of any algae, diatoms, sediment, overlying soft tissues, etc.; overlying soft tissues would have died within the previous minutes-days; conspicuous during outbreaks of disease, bleaching-related mortality events, after hurricanes or other large-scale perturbations.

      Transitional mortality (% Trans Mortality on the UW Datasheet)–any non-living parts of the coral in which the corallite structures are slightly eroded at most, yet the coral is still identifiable to species and its surface is covered by a thin layer of sediment, algal turfs, diatoms or cyanobacteria films; overlying soft tissues are presumed to have died within the previous days-months.

      Old mortality 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.,* many macroalgae and invertebrates); or (b) the overgrowing organisms have been removed by a scraping herbivore *(e.g.,* stoplight parrotfish, *Sparisoma viride*) or abraded by a storm; or (c) both the overgrowing organisms and the outer corallite structures have been removed by parrotfish bites or extreme

[10] Link in online version to corresponding definitions in **AGRRA Stony Coral Survey Objectives** section in **Changes in V.5**

storm damage, exposing the interior of the skeleton; in each case the soft tissues of the original coral are presumed to have died within the previous months-years or decades.
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 (=zooxanthellate clionid overgrowth) in the corresponding Comments box.

If the coral is **completely dead over its entire surface**, note SD (standing dead) in Comments providing you can identify it to species (e.g., *Acropora palmata* by gross morphology*; Montastraea cavernosa* by polyp size and shape), species complex (e.g., *Montastaea annularis* complex, digitate *Porites*), or genus (e.g., *Diploria* by size of meandering ridges and valleys).

How to assess corals that are detached from the substratum:

- *If **recently fallen**, the size measurements and condition assessment should be made as if still upright; write FELL in the corresponding Comments box.*

H = maximum height
L = maximum length

- *If **detached but wedged** (i.e., likely to remain in this position for an extended period), measure as for recently fallen and write WEDGE in the corresponding Comments box.*

- *If **fallen and reoriented to grow upward** in a new position, measure the new size dimensions, use the new outward-facing surface for estimating % mortality, and write "FELRO" (for "fallen, reoriented") in the corresponding Comments box.*

e. Examine all surviving portions of the coral and note the presence of any signs of disease and/or bleaching.
Minimum for Disease: put ?√ (question mark check) in the Disease box if new mortality is common on corals that are in intact positions and not bleached.
Complete for Disease: Code signs of disease as:
BB = Black band

RB = Red band
WB = White band *(Acropora* only)
WS = White spots/white patches/white pox/patchy necrosis *(Acropora* only)
WP = White plague
YB = Yellow band (formerly yellow blotch)
UK = Unknown

***Optional**: If unknown, describe (e.g., as location on colony, condition of the interface between remaining live tissues & exposed skeleton, and whether or not adjoining tissues are bleached) in the corresponding Comments box, then try to match your observations with one of the characterized diseases after the dive.*

For more information about coral diseases see any of the following:

Bruckner, A. (2002) Appendix II Coral Health and Mortality. Recognizing the signs of coral diseases and predators. Pp. 240-278 in P. Humann, ed., Reef Coral Identification. New World Publications, Inc.
http://www.coris.noaa.gov/about/diseases/
http://www.coral.noaa.gov/coral_disease/

Bleaching should be coded by approximate severity of discoloration as:
P = Pale (relative to what is considered "normal" for the species and location)
PB = Partly Bleached (patches of fully bleached tissue)
BL = Bleached (tissue is fully bleached, no zooxanthallae visible)

Many severely bleached corals are translucent, 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 translucent. Bleached tissues are alive, and must not be included in the estimate of new mortality.

f. For ***complete***-level surveys
Put a check in the DF box if there are any damselfish bites or algal gardens anywhere on the coral.

Record in the Comment box any other sources of mortality as can still be unambiguously identified anywhere on the coral. Possibilities and common acronyms include:
Physical damage from sediments or storms
Parrotfish bites (PFB)
Predation on the soft tissues by snails like *Corallophilia abbreviata* (CABB) or the bristle worm *Hermodice carunculata* (HCAR)
Overgrowth by benthic macroalgae or by invertebrate competitors (use the Benthic Cover/Abundance Survey point-count codes)

How to assess large clusters or thickets in which colony boundaries are not distinguishable:

i. Write PC ("Point Counts") in the Comments box.

ii. Measure the maximum length, maximum width, and maximum height for the clump as a whole.

iii. Using the 1-m pole for scale, in the Comments box, record the condition of the points at 10-cm intervals across the widest part of the colony as # live (L), # new mortality (NM), # transitional mortality (TM) and # old mortality (OM) (i.e., 9L, 0NM, 4TM, 7OM represents a total of nine live points, zero new mortality, four transitional mortality and seven old mortality).

iv. Record any signs of disease, bleaching, overgrowth, etc., for the clump as a whole.

6. After you complete the corals on one side of the transect, check your bottom time and air supply:
   - If remaining time dive and available air both permit, swim back along the second side of the line; assessing all ≥ 4 cm corals that are at least 50% within a .5-m wide belt

Be careful not to resurvey any coral that underlies the line and was previously assessed during the first

transect.

- If you don't have enough remaining time and/or air, tally the numbers of each species of stony coral within the .5-m wide belt on the second side of the line. Record the areas in which corals were respectively surveyed or counted at the top of your datasheet.

In high-relief reefs it may be easier to survey both sides of the line at the same time. However, it is still important spread your assessment along the line in reefs containing too many stony corals to complete the entire 10 m^2 survey within one dive.

Optional: *Before the dive write a set of random numbers on your datasheet to determine the order of surveying the meters.*

Try to assess a minimum of $5m^2$. Tally the numbers of each species of stony coral in the remaining area of the belt, and record the areas in which corals were respectively surveyed or counted at the top of your datasheet.

7. Release the tie-off at the 10-m end and rewind the line on the quadrat as you swim back to the 0-m end, then release and attach its tie-off to 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 counted and recorded to species.

   This information is crucial for later coral density estimates, and is especially important whenever a dive has to be terminated before completing the surveys or counts.

8. After diving: enter your data, including comments, on a daily basis into the **Corals** sheet of an AGRRAspreadsheetV5.0.xls. Be sure to use a **separate** copy of the spreadsheet for **every site**, and check your transcribed data to verify its accuracy. Back up your own data regularly and store it in a safe place.

9. Once the team leader has signed off on your spreadsheets, and safely stored the original UW datasheets, the data are ready to be emailed to:

   data@agrra.org

Optional Addition at Step 7

Use the margins of the datasheet to record this information.

Damselfishes tending algal gardens in stony corals

7A. After finishing the stony coral survey, slowly swim along the transect line with the 1-m pole held horizontally and centered on the line. Tally all damselfish that defend bites or algal gardens located on any stony coral within the belt.

C. Fish Surveys (two divers)

Integrating the fish and benthos sampling requires coordination among team members. The fish transects should be located in the same habitat as the benthic and coral transects, however, they will tend to be further apart, and may range in slightly deeper or shallower water.

Many fishes are wary of humans; hence, as much as is possible, you should to try to keep away from other divers. To minimize disturbance to the fishes, counts are made at the same time as the tape is released, rather than over a tape after it has been set on the substratum. Ideally, the fish transects should be conducted between 1000 and 1400 hours when visibility underwater is at a maximum due to overhead sunlight–we recognize this is impossible whenever multiple sites are sampled throughout daylight hours.

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 and estimating fish sizes underwater, and in measuring maximum reef relief. **Retraining on a week basis during expeditions is strongly encouraged.**

Surveying with a standardized list of fishes allows a relatively consistent search image, which should facilitate accurate species identifications and reliable estimates of their sizes.

Method

1. At each **site**, record the following information on your UW **FISH** datasheet before the dive:
   Recorder: 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 generic description of location
   Day #: sequential, if during an expedition (1, 2, 3, etc.)
   Site #: sequential each day (1, 2, 3, etc.)
   Latitude & Longitude as determined by DGPS (or best available instrument) at the site; **note if corrected from a boat or other fixed position**[4]
   AGRRA Location Code: sequential as a 3 letter + 2-3 digit code *(e.g.,* BAH01, BAH02, BAH03, etc.)

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 a D-ring on your weight belt or BCD to allow the tape to be easily released without having to hold the reel in your hands.

3. Record when you start the first transect in **Start Time** and write 1 in the Transect # box. 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.

   Count all AGRRA fishes (at the ***minimum-*** or ***complete-***level) located within a belt that is 2-m wide and extends up through the water column to the water surface, giving uniform attention to each successive 2-m segment of the transect. Estimate the width of the belt with the T-bar. Estimate the size of each fish with the 10-cm increments on the 1-m T-bar, and assign them to the following size categories: < 5 cm; 5-10 cm; 11-20 cm; 21-30 cm; 31-40 cm; > 40 cm. Classify large schools of fishes by putting them into one or more size categories and approximating the number of individuals to the nearest 10 or 100 depending on the size of the school. Count only those members of a school crossing the transect that happen to be within the 2-m segment that is immediately in front of you at any given time.

   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 6-8 minutes should be attempted, however, high densities of counted species could slow this pace.

Frequently encountered species and families are listed by their common names on the UW FISHES datasheet. Fill in the name of any unlisted species present at the site in the appropriate blank space associated with its family or under "Others" at the base of the datasheet. Briefly describe and sketch any unknown/unfamiliar fish species in the margin of the UW datasheet. Body shape and behavior (swimming with pectoral finds, lying on bottom, etc.) may help later to identify its family. Colors and notable markings (spots, lines, etc.) can be essential in determining its species name.

4. When you reach the end of the transect line:
   If your tape is marked in meters, use your T bar to delineate a 1-m radius of the 30-m mark, and then to measure the height of the tallest coral or reef rock above the lowest point in the underlying substratum. Enter this number (in cm) into the 30 m box for Max. relief. As you reel in the tape, pause to measure maximum relief as above at its 25-, 20-, 15-, 10- and 5-m marks.
   *Do **not** use your depth gauge to estimate maximum relief.*

   If your tape is marked in feet, reel it in to the 90 ft mark, and use your T bar to delineate a 1-m radius of this mark, then measure the height of the tallest coral or reef rock above the lowest point in the underlying substratum. Enter this number (in cm) into the 90 ft box for Max. relief. As you reel in the tape, pause to measure maximum relief as above at its 75-, 60-, 45, 30- and 15-ft marks.
   *Do **not** use your depth gauge to estimate maximum relief.*

5. Continue conducting haphazardly-positioned 30-m transects at least 5 m laterally away from your previous position and other divers until a total of 10 transects has been completed between the 2 divers.

6. After diving: enter your data, including comments, on a daily basis into the **Fishes** sheet of an AGRRAspreadsheetV5.0.xls. Be sure to use a **separate** copy of the spreadsheet for **every site**, and check your transcribed data to verify its accuracy. Back up your own data regularly and store it in a safe place.

7. Once the team leader has signed off on your spreadsheets, and safely stored the original UW datasheets, the data are ready to be emailed to:
   data@agrra.org

Optional Addition after Step 5

Rover Diver census

Conduct a roving diver census in the same general area as the fish belt transects, following the methodology of Reef Environmental Education Foundation (REEF) (http://www.reef.org/) as briefly explained below.

1. Swim around the reef site for approximately 45-60 minutes and record **every fish species** observed on a copy of the REEF UW paper. Use all knowledge you have of fish habits, and be sure search under overhangs, in caves, etc. The objective is to find as many species as you can in during your search time.

2. Estimate the **density** of each species by using the following logarithmic categories:
   Single (1fish)
   Few (2-10 fishes)
   Many (11-100 fishes)
   Abundant (>100 fishes)

3. Record your observations on a REEF data-entry bubble sheet.

OPTIONAL COMPONENTS

Several other useful assessments may be easily integrated into the core portion of the protocol given above if you are able to allocate more than one dive at each survey site. These optional components, while not part of the core methods, can yield additional information that may lead to a better understanding of the condition of a reef. For some you will need to construct appropriate UW datasheets.

Stony Coral Recruitment

Coral recruitment, which is an important indicator of a reef's regeneration potential, is now an optional addition in the AGGRA benthos protocols. To obtain results that are statistically more reliable, use the method described at the benthic cover/abundance protocol to tally all stony coral recruits in an additional 10, haphazardly set, 10-m long transects at the survey site.

Stony Coral Species Richness

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

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   Single (1fish)
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   Abundant (>100 fishes)

3. Record your observations on a REEF data-entry bubble sheet.

4. Submit data to REEF.

Herbivory

The objective of the Steneck's (1985) Fish Bite Method is to count the number of bites observed per square meter within a standard time in order to gauge the effect of herbivorous fishes on algal composition. Different guilds of herbivorous fishes are categorized as:

Excavators/Scrapers = scarids (parrotfish)
Denuders/Browsers = acanthurids, (surgeonfish), *Microspathodon chrysurus* (yellowtail damselfish), kyphosids (chubs), *Melichthys niger* (black durgon)
Non-denuders = other pomacentrids (damselfish) but not *Stegastes partitus* (bicolor damselfish)
You must be able to distinguish:
(a) juvenile scarids from other fishes with similar stripes, such as acanthurids and labrids (wrasses–which only look as though they are biting algae as they search for small invertebrates);
(b) yellowtail damselfish (which are browsers) 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 square 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 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 (identify them to species as best as you can).

3. Repeat for a total of 5 squares (and ~25 minutes observation).
   Be sure to remember to record the time of day since fish activity varies temporally.

Reference

Steneck, R.S. 1985. Adaptations of crustose coralline algae to herbivory: patterns in space and time. pp. 353-356, in: D.F. Tooney amd M. H. Nitecki eds., Paleoalgology: Contemporary Research and Applications. Berlin-Heidelberg. Springer-Verlag.

Fish Memory Cues (common AGRRA species)

Angelfishes

Queen Angelfish
The Queen has a crown (dark blue spot on forehead ringed with bright blue).

French Angelfish
This fashionable French beauty is dressed in classic black (with gold highlights).

Gray Angelfish
As its name implies, the Gray is gray to grayish brown.

Rock Beauty
This little beauty is yellow and black. The juvenile is bright yellow with a small black spot (ringed in blue). The black spreads as the fish grows covering most of the fish as an adult.

Butterflyfishes

Banded Butterflyfish
White with black bands (thick diagonal black markings).

Foureye Butterflyfish
Large false “eyespots” near tail.

Spotfin Butterflyfish
Small black spot on the rear of the bright yellow dorsal fin.

Reef Butterflyfish
Uncommon – identification by process of elimination (no good memory clue).

Longsnout Butterflyfish
Tiny fish with long pointy snout (as name implies). Usually found deep.

Surgeonfishes

Blue Tang
Blue with contrasting yellow “tang” (spine on base of tail). Juveniles change from all yellow to combination of yellow and blue to all blue as adult.

Ocean Surgeonfish
Clear pectoral fin – think “Clear Ocean”. Leading edge of pectoral fin clear to yellowish but never opaque.

Doctorfish
Dark pigmented leading edge of pectoral fin – think “Dark Doctor.”

Silvery (Miscellaneous)

Bar Jack
Most common jack with black and blue “crowBAR” along back and onto lower tail fin.

Permit
Rounded shape due to high back profile. Orange area at base of anal fin.

Great Barracuda
Large, silvery, toothy torpedo. Most divers (and non-divers) know this species.

Sheepshead Porgy
Small black spot at base of pectoral fin. Upper jaw overbite.

Saucereye Porgy
Bluish saucer-shaped line below eye.

Jolthead Porgy
Large mouth with thick lips. Yellow-orange at corner of mouth.

Pluma
Blue rectangular patch behind eye.

Grunts

French Grunt
Diagonal gold markings like the gold braids worn on a French General’s uniform.

Bluestriped Grunt
Blue horizontal stripes over yellow body. If pale in shallow water, black rear dorsal and tail fin are good ID cue.

Smallmouth Grunt
Small grunt – (Small Mouth). Silvery fish with horizontal yellow lines and yellow fins.

White Grunt
All fins white. Body checkered pattern of pearly white, blue & yellow formed by scales. Thin stripes only on head.

Caesar Grunt
Silvery with thin yellow lines like raw egg drizzled over a Caesar salad. Dusky rear dorsal, anal, and tail fins like the dusty feet of Caesar’s army.

Tomtate
Whitish fish with two thin yellow lines (one midbody through eye, the other on back). Usually a black spot at base of tail. Think of a Tom-Tom (a small drum) with the two yellow lines as drum sticks.

Cottonwick
Black line from the snout through the eye fades as it reaches the tail. Think of the black cotton wick of a candle. Usually have a black diagonal stripe that runs along the back and onto the tail.

Spanish Grunt
Large grunt with horizontal black lines and a yellow saddle on the base of the tail. Think of the fried egg in a Spanish omelet.

Sailors Choice
Silvery gray fish with distinctive black spots on scales covering the body; gold ring encircles the eye. Think pirates (who were sailors) with the black spots as rows of waves and the gold ring as a golden earring.

Porkfish
Two black diagonal bands on head (one through eye and the other just behind the gills). For pork, think of the bands as two strips of overcooked bacon.

Black Margate
The large black patch on the side of this fish makes the Black Margate easy to remember.

White Margate
About the size of a Black Margate but without the black patch. Very steep forehead with high back profile. Eye is tiny with white iris.

Snappers

Mutton Snapper
This species is easiest to ID if you know that its scientific name is *analis* since it is the only snapper with a pointed (not rounded) anal fin. It usually has a small black spot on the back ("the button on the Mutton") which we can use to remember its common name.

Cubera Snapper
This is the largest of the snappers (up to 3'), usually solitary, and often with pale bars across back.

Gray Snapper
Gray with no distinguishing features other than a dark diagonal band that occasionally runs from lip across eye.

Dog Snapper
Has "teardrop stains" below eye. For the girls we say the fish is crying because it lost its dog; for the guys we go for the more macho memory cue of "dog tags".

Mahogany Snapper
Silvery white fish with "Mahogany" red margin on tail; sometimes reddish tinge on body or other fins.

Lane Snapper
Though sometimes faint, this fish has yellow "lane" markers (think highway) along its body. It may have a small black spot just below the rear dorsal.

Yellowtail Snapper
Bright yellow midbody stripe continues onto yellow tail. Feed in the water column high above reefs.

Schoolmaster
Large silvery white fish with all yellow fins. Think of a yellow school bus when you see the yellow fins.

Damselfishes

Yellowtail Damselfish
The only damselfish we need to know and one of the easiest to remember as it has a yellow tail. Juveniles are bright blue with brilliant blue spots. The tail is translucent on very young juveniles.

Groupers/Sea Basses

Nassau Grouper
The black saddle is the easiest way to ID this fish. Think “Ride the Nassau Grouper back to the Bahamas”.

Graysby
Most common of the smaller groupers. Grayish brown with 3-5 pale or dark spots along back along base of dorsal fin. Think of the pairs of spots along the back as bullet holes – the fish was “grazed” by gunfire.

Red Hind
Reddish spots over a lighter background rear fins (rear dorsal, tail, and anal) edged in black. Think “RED with a black beHIND”.

Rock Hind
Have a black saddle (and usually additional black blotches along back under the dorsal fin). Think of these spots as “rocks”.

Coney
This variable species can be reddish brown, bicolor (upper dark lower pale), or a brilliant yellow so color is not a good ID cue. The body is usually covered with tiny blue spots. One constant is that it has two spots on the lower lip and two on the base of the tail.

Black Grouper
Blotches on back squarish. Think “Black Bricks” or “Black Blocks”.

Tiger Grouper
Have “tiger-strips” across back. Also have some pretty impressive canine teeth.

Yellowmouth Grouper
Corners of the mouth a distinctive yellow. Margins of pectoral fins pale.

Yellowfin Grouper
Margins of pectoral fins yellow. Blotches on back are more oval and not squarish like the Black Grouper.

Parrotfishes

Blue Parrotfish
Adults are blue with no markings. Juveniles have a yellow wash on the head.

Midnight Parrotfish
Dark navy (“midnight”) blue with some lighter blue on body (especially on head).

Rainbow Parrotfish
“Rainbow” colored with orangish head and tail and bright green rear body.

Queen Parrotfish
TP: Queen has a moustache and beard (blue/green markings around mouth).
IP: Black and white like a chess board.

Stoplight Parrotfish
JP & IP: Bright red belly (like a stoplight).
TP: Small yellow spot at top of gill cover. (Like the yellow light in a middle of a traffic light?)

Princess Parrotfish
TP: Tail bordered with pink. Think “Pink Princess”.
JP: Looks like the Striped Parrotfish juvenile but doesn’t have a gold nose. Think “The Princess has no gold”.

Striped Parrotfish
TP: The tail is not bordered in blue (not pink like the “Pink Princess”).
JP: The Princess Parrotfish may be royalty but it is the Striped that has the gold (on its nose).

Redband Parrotfish
Exceedingly variable parrotfish. Only the TP have the namesake “redband” across the cheek. In all of the other JP/IP color variations, look for the white spot (saddle) on the base of the tail.

Redtail Parrotfish
TP: Red crescent in the middle of the tail.
IP: Red tail (and body) – mostly reddish gray can be pale.

Yellowtail/Redfin Parrotfish
Name comes from small reddish spot at base of pectoral fin but yellow tail is usually more visible. I always remember this fish by both of its names when I see it and think “yellowtail => redfin”.

Greenblotch Parrotfish
Tiny parrotfish named Greenblotch for the green blotch on the side of the TP. The JP/IP are usually red to yellowish red. All phases have a bright yellow-gold to red iris.

Wrasses/Hogfishes

Hogfish
The spiky front dorsal fin is like the bristles on the back of a razorback hog.

Spanish Hogfish
Think of the purple area across the top of the body as stain from a bottle of Spanish wine.

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White splotches on back of common intermediate phase.

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Dark spot on upper part of gill cover.

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Balloonfish
Long spines all over body especially on head. No black spots on fins.

Porcupinefish
Black spots on all fins.

Leatherjackets (Triggerfishes & Filefishes)

Queen Triggerfish
The Queen is long eyelashes (the black lines radiating from the eyes) but like the Queen Parrotfish, she has a blue moustache.

Ocean Triggerfish
Uniformly gray and usually swimming high in the water column. Has a black spot at base of pectoral fin.

Black Durgon
Usually black overall (with pale bluish white lines along base of dorsal and anal fins. Can have a bluish or greenish cast.

Whitespotted Filefish
Large orange, brown and gray colored fish often with large white spots. Commonly seen in pairs with one fish showing spots, the other without. Pair of orange spines at tail base.

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Dusky brownish color with small orange spots (more intense on back and toward tail). Small white saddle on tail is distinctive.

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CORAL CRIB SHEET for the TROPICAL NORTHWESTERN ATLANTIC

ACER	*Acropora cervicornis*	MMEA	***Meandrina meandrites***
APAL	***Acropora palmata***		
APRO	*Acropora prolifera*	**MALC**	***Millepora alcicornis***
		MCOM	***Millepora complanata***
AAGA	***Agaricia agaricites***	MSQU	*Millepora squarrosa*
AAGAC	*A. agaricites f. carinata*	**MILL**	***Millepora* sp.**
AAGAD	*A. agaricites f. danai*		
AFRA	*Agaricia fragilis*	**MANN**	***Montastraea annularis***
AHUM	*Agaricia humilis*	**MCAV**	***Montastraea cavernosa***
AGRA	*Agaricia grahamae*	**MFAV**	***Montastraea faveolata***
ALAM	***Agaricia lamarcki***	**MFRA**	***Montastraea franksi***
ATEN	***Agaricia tenuifolia***	**MONT**	***M. annularis* complex**
AUND	*Agaricia undata*		
AGAR	***Agaricia* sp.**	**MANG**	***Mussa angulosa***
CNAT	***Colpophyllia natans***	MALI	*Mycetophyllia aliciae*
		MDAN	*Mycetophyllia danaana*
DCYL	***Dendrogyra cylindrus***	MFER	*Mycetophyllia ferox*
		MLAM	*Mycetophyllia lamarckiana*
DSTO	***Dichocoenia stokesi***	**MYCE**	***Mycetophyllia* sp.**
DCLI	***Diploria clivosa***	**OCUL**	***Oculina* sp.**
DLAB	***Diploria labyrinthiformis***		
DSTR	***Diploria strigosa***	**PAST**	***Porites astreoides***
DIPL	***Diploria* sp.**	PDIV	*Porites divaricata*
		PFUR	***Porites furcata***
EFAS	***Eusmilia fastigiata***	**PPOR**	***Porites porites***
		PORI	***Porites* sp.**
FFRA	*Favia fragum*		
		SCUB	*Scolymia cubensis*
IRIG	*Isophyllastrea rigida*	SLAC	*Scolymia lacera*
		SCOL	***Scolymia* sp.**
ISIN	*Isophyllia sinuosa*		
		SRAD	*Siderastrea radians*
LCUC	***Leptoseris cucullata***	**SSID**	***Siderastrea siderea***
		SIDE	***Siderastrea* sp.**
MARE	*Manicina areolata*		
		SBOU	*Solenastrea bournoni*
MAUR	***Madracis auretenra (ex mirabilis)***	SHYA	*Solenastrea hyades*
MDEC	***Madracis decactis***	SOLE	*Solenastrea* sp.
MFOR	***Madracis formosa***		
MADR	***Madracis* sp.**	**SINT**	***Stephanocoenia intersepta***

Diseases

BB = Black band
RB = Red band
WB = White band *(Acropora* only)
WS = White spots *(Acropora* only)
WP = White plague
YB = Yellow band
UK = Unknown

Bleaching

P = Pale
PB = Partly Bleached
BL = Bleached

Algae

CCA = Crustose Coralline Algae
PLN = *Porolithon*
PEY = PEYssonnelids
CYAN = CYANobacteria
TA = Turf Algae
FMA = Fleshy Macro Algae
or **DIC**= *Dictyota*
or **LOB** = *Lobophora*
or **name** = Name of FMA
CMA = Calcareous Macro Algae
or **HAL** = any *Halimeda* sp.
or **HAM** = *Halimeda* Mat
or **HGM** = *H. goreauii* Mat
or **HOM** = *H. opuntia* Mat
or **name**= Name of CMA
FCMA = mixtures of FMA & CMA

OINV = Other (non-aggressive) invertebrate

or **SPO** = Epibenthic sponge
or **GOR** = Gorgonian holdfast
or **name** = Name of OINV

AINV = Aggressive Invertebrate that Kills & Overgrows Corals and Crustose Coralline Algae

or **CRED** = *Cliona delitrix* (Red)
or **CZOO** = Zooxanthellate *Cliona* (Brown/Black)
or **CHON** = *Chondrilla caribensis*
or **BRI** = *Briareum asbestinum*
or **ERY** = *Erythropodium caribaeorum*
or **PAL** = *Palythoa caribaeorum*
or **TRI** = *Tridemnum solidum*
or **name** = Name of AINV

For Underwater data sheets, see the following Excel files:

BENTHIC-UW-V5.0.xls
CORALS-UW-V5.0.xls
FISHES-UW-V5.0.xls