

APPENDIX ONE

THE ATLANTIC AND GULF RAPID REEF ASSESSMENT (AGRRA) PROTOCOLS: FORMER VERSION 2.2

BY

PATRICIA RICHARDS KRAMER¹ and JUDITH C. LANG²

INTRODUCTION

The AGRRA methodology is the result of an on-going international collaboration of reef scientists and managers. Since its initiation in 1995, the methods have undergone a series of iterations (Table 1) in response to recommendations from the organizing committee and our colleagues. Version 2.2 of the AGRRA method is briefly summarized below as it was the version used for many of the assessments reported in this volume. Sections that have been changed in subsequent versions are underlined. Specific deviations from this or other versions of the protocols are detailed in the individual papers of this volume. For more information on *the current version of the methodology*, data-sheet templates, survey equipment, and the AGRRA approach, see the AGRRA website (<http://coral.aoml.noaa.gov/agra/method/methodhome.htm>).

One of the main objectives of the AGRRA approach is to provide a standardized methodology enabling teams working in different areas to collect and compare data on a regional scale. With visual censuses, it is particularly important to minimize individual bias among observers. Hence, it is essential to carefully standardize methods prior to data collection. Suggestions for consistency training and calibration can also be found at the AGRRA website.

SELECTION OF REEFS AND SITES

For the purposes of AGRRA, a region is defined as the coarsest scale category (~100-1000 km scale); followed by an area (~10-100 km scale); a reef (~1-10 km scale); and a site (0.2 km scale).

The method for selection of reefs to assess will be influenced in part by their local abundance and distribution and by the sampling effort to be undertaken. Whenever the extent and/or number are too large for complete sampling, the reefs should be subdivided or “stratified” and examples selected from within each subdivision. All good sources of information (benthic maps, aerial photographs, remote images, charts, local knowledge, reconnaissance by Manta tow-board, etc.) should be employed to separate the reefs into

¹ Marine Geology and Geophysics, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL, 33149.
Email: kramer_p@bellsouth.net

² P. O. Box 539, Ophelia, VA 22530. Email: JandL@rivnet.net
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subdivisions on the basis of geographic distribution and by secondary characteristics such as size, depth range, and position relative to land. If there are no clear bases for making subdivisions (e.g., a continuous bank barrier or fringing reef several kilometers long), a numbered grid 200 m long can be superimposed along a chart or image of the reef, with each number representing a potential survey site. Hardgrounds, pavements and other habitats that lack a framework constructed of reef-building corals should be avoided.

Once reefs are stratified, depending on the methods and resources available for use, the ones that are selected for survey will generally fall into one of three categories:

1. Unbiased—chosen on the basis of a random sampling strategy;
2. Representative—chosen with local knowledge to be representative of reefs in the area;
3. Strategic—chosen with local knowledge and for a purpose (e.g., they are considered threatened, degraded or in particularly good condition).

For regional comparisons, it is best to have reefs that are chosen by either category (1) or (2). Reefs chosen by (3) should be clearly flagged as such.

A site is defined as an area of habitat of 200 m x 200 m (or less) that is more or less homogeneous and accessible from a boat anchored or moored in one place. Two habitats of maximum reef development of particular interest are the ~1-5 m depth interval (shallow *Acropora palmata* zone) and the ~8-15 m depth interval (shallow fore reef or equivalent). Whenever possible, one site within each of these depth intervals should be surveyed on each reef chosen for an AGRRA assessment. The site description for each survey site should include an explanation of how the site was selected.

BENTHOS (STONY CORALS, ALGAE AND *DIADEMA*)

1. At each site, haphazardly lay a 10-m transect line (marked in 2 m intervals) just above the reef surface (= taut) in a direction that is approximately parallel to the long axis of the reef. Be sure to avoid or cross any other transects. Stay away from the edges of the reef and try to avoid areas with abrupt changes in slope, deep grooves, large patches of sand or unconsolidated coral rubble. Unusual reef features should be included only to the extent appropriate to their relative abundance at the site.
2. Record total live stony coral (scleractinians + *Millepora*) cover under the transect line (to the nearest 10 cm) with a measuring tool (e.g., a 1-m long PVC pipe marked in 10 cm intervals). If the reefs are too small to avoid sandy patches, record how much of the line crosses sand (for later calculation of live stony coral cover/m of reef hard reef substratum).
3. Swim along the transect line, stopping at the first stony coral (Table 2) located directly beneath the line that is at least 25 cm (or, if preferred, at least 10 cm) long and in original growth position or, if fallen, has either become reattached to the substratum or is too large to move. Record each of the following:
 - A. Name (genus and species)
 - B. The water depth at the top of the colony at the beginning and end of each transect and at any major change in depth (>1m).

- C. After identifying the colony boundaries based on common skeletal connections among the living polyps and similarities in their size and color, record maximum colony projected diameter (live + dead areas) perpendicular to the axis of growth and maximum height (live + dead areas) above the substratum parallel to the axis of growth.
- D. Percentage estimates of the coral that are “recently dead” (corallite structures are white and either still intact or covered by a layer of algae or fine mud; include fish bites) and “old dead” (corallite structures are either gone or covered by organisms that are not easily removed, including brown encrusting clionid sponges) as viewed from above at an angle that is parallel to the axis of growth. If the entire coral has been dead a long time and can still be identified, at least to generic level based on gross (e.g., *Acropora palmata*) or skeletal (e.g., *Diploria*) morphology, score as 100% “old dead.”
- E. Evidence anywhere on the entire colony of–
- Any diseases, using the following color categories:
 - BB = Black band
 - WB = White band
 - WS = White spots, patches or pox
 - WP = White plague
 - YB = Yellow blotch (sometimes called yellow band)
 - RB = Red band
 - UK = Unknown

Underline any disease visible on the upper colony surface that contributed to the estimate of “% recent dead.”

- Bleached tissues as approximate severity of discoloration:
 - P = Pale (discoloration of coral tissue)
 - PB = Partly bleached (patches of fully bleached or white tissue)
 - BL = Bleached (tissue is totally white, no zooxanthellae visible)
- All other sources of recent mortality that can still be unambiguously identified, such as sediment, storm damage, parrotfish bites, damselfish bites and/or algal gardens, predation (e.g., by *Corallophilia abbreviata* or *Hermodice carunculata*), and spatial competitors (e.g., benthic algae, invertebrates like *Erythropodium caribaeorum* or other stony corals). Underline any that contributed to the estimate of “% recent dead.”
- Algal gardens established by damselfish (in live parts of the coral as numbers of resident fishes and/or the presence of their gardens).

For large clusters or thickets in which colony boundaries are not distinguishable, use a standard point-count method to identify recent death, old death, or living coral tissue every 25 cm along the line. The maximum diameter and height should be determined for the entire cluster or thicket.

4. Go to the next appropriately sized coral and repeat step 3 above. Continue evaluating each coral until reaching the other end of the transect line.

5. Reswim the transect with the 25 x 25 cm algal quadrat. Starting at 1 m, place the quadrat every two meters directly below the transect line (i.e., at 1,3,5,7,9 m). If any of these area are unsuitable (i.e., <80% is covered by algae of any functional group), place the quadrat on the nearest available space within a 1 m radius of the mark. If no suitable areas are present, draw a line through the space on the data sheet. For each quadrat that is in a suitable area, remove any thin layers of sediment that could cover crustose coralline algae and record each of the following:
 - A. Substratum type;
 - B. % of macroalgae (all larger erect fleshy algae >1 cm in height; both fleshy and calcareous);
 - C. % of algal turfs (mostly tiny filaments, <1 cm in height), including any below the canopies of macroalgae;
 - D. % living crustose coralline algae (solid, calcareous encrusters that are pink or reddish in color, include any that are clearly visible below turf algae or a thin layer of sediment);
 - E. By using the plastic ruler for scale, the average canopy height of the macroalgae in the quadrat.
 - F. Optional—the number of all small (up to 2 cm maximum diameter) stony corals (scleractinians and *Millepora*) in the quadrat and, whenever possible, their identity to the genus level.
6. Swim along the transect, counting every *Diadema antillarum* (juveniles and adults) that can be seen within a belt extending 1/2 m on each side of the line.
7. Collect the line and haphazardly reset it at least 1 m laterally away from its previous position, following previous guidelines. Try to distribute transects around the survey site.
8. Repeat steps 2-6 for each transect. Continue to reset transects until a minimum of 100 corals and 50 quadrats have been assessed.
9. Enter transect data into the AGRRA benthos spreadsheet. After checking for accuracy, submit an electronic copy to agrra@rsmas.miami.edu. Back up data regularly and store in a safe place.

FISH

The following two distinct assessment methods should be applied at each site. Whenever possible, they should be conducted between 1000 and 1400 hours. As many fishes are wary of humans, it is important to try to keep away from other divers.

Method I. Belt Transects for AGRRA Species.

All belt transects used for fish assessments should be located within the same general habitats and depth intervals (i.e., at 1-5 m and 8-15 m) as the benthic transects, but they will tend to be further apart and may range into deeper and shallower water.

1. Lay a 30 m transect by first placing the weighted end of the tape on the bottom and then swimming in a straight line (by periodically fixing on a distant object) while releasing the tape from the reel, which can be clipped to the weight belt for easy release.
2. Swim at a more or less constant rate holding a 1-m wide T-bar (with 5 cm increments for scale) angled downward at about 45 degrees while looking consistently about 2 m ahead of the T-bar. Within a belt visually estimated to be 2 m wide, count only the fish listed in Table 3 (also listed on the data sheet), while using the T-bar to estimate the size of each fish within one of the following size categories (<5, 5-10, 10-20, 20-30, 30-40, >40cm). If necessary, pause while recording data and then resume swimming. Do not count juvenile parrotfishes and grunts <5 cm in total length. Large, intraspecific groups can be classified into one-or-more size categories as necessary. By keeping an equivalent effort on all segments of the transect, the tendency to count all members of a school crossing the transect, instead of just those members which happen to be within the belt as counting of its segment takes place, can be avoided.
3. Recoil the tape and haphazardly redeploy at a distance of least 5 m laterally away from the previous position.
4. Repeat steps 1-3 for each transect. Continue to reset transects until a minimum of 10 transects have been completed.
5. Enter belt-transect data into the AGRRA fish spreadsheet. After checking for accuracy, submit an electronic copy to agrra@rsmas.miami.edu. Back up data regularly and store in a safe place.

Modifications. Researchers wanting to census other species of fish are encouraged to do so on a separate pass over the transect, after the completing counts of AGRRA fishes.

Method II. Roving Diver Technique

After finishing the belt transects (or concurrently depending on the number of surveyors), a census of all species of fishes should be conducted in the same general depth and habitat as the belt transects, following the methodology of the Reef Environmental Education Foundation (REEF) (see <http://www.reef.org/>) and briefly explained below.

Pp. 611-624 in J.C. Lang (ed.), Status of Coral Reefs in the western Atlantic: Results of initial Surveys, Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program. Atoll Research Bulletin 496.

1. Swim around the site for approximately 30 minutes (preferably 45-60 minutes), searching under overhangs, in caves and so on to find as many fish species as possible.
2. By the end of the dive, estimate the density of each species by using logarithmic categories: Single (1 fish), Few (2-10 fishes), Many (11-100 fishes), or Abundant (>100 fishes) and summarize these observations on a standardized REEF data entry sheet.
3. Transcribe the data on a standardized REEF Scantron sheet and send to REEF HQ, at P.O. Box 246, Key Largo, FL 33037, USA.

OPTIONAL COMPONENTS

Stationary Plot Fish Survey

The Stationary Plot Technique (Bohnsack and Bannerot, 1986), outlined below, has been used extensively in the Caribbean and the Florida Keys to provide data on abundance and size for a wide range of fish species. Its use is encouraged as a third way to quantify fishes at each site, but not as a replacement for Method I or II.

1. Count the number of fish observed in a visually estimated cylinder (radius of 7.5 m) for a period of five 5 minutes.
2. Estimate and record the length of each fish counted.

Herbivory

The Fish Bite Method (Steneck, 1985) can be used to gauge the effect of certain herbivorous fishes on algal composition in the survey sites. Herbivorous fish guilds are categorized as:

Scrapers = Scaridae (parrotfish)

Browsers = Acanthuridae (surgeonfish), *Microspathodon chrysurus* (yellowtail damselfish)

Non-denuders = other Pomacentridae (damselfish)

1. Use a metric scale 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 at the site. (Do not place a meter quadrat on the substratum as some fish are particularly prone to biting novel objects placed within their feeding territories).

Back off as far as possible while still being able to see the meter-square area. Watch for five minutes. Record the depth, time of day, and number of bites from all species of fishes in the three guilds listed above, whenever possible identifying them to

species. It is necessary to 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 amphipods to eat) and (b) yellowtail damselfish (which are browsers) from the species of damselfish that cultivate algal gardens.

2. Repeat for a total of five quadrats (and ~25 minutes of observation).

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Table 1. Timeline of the development of the AGRRA methodology.

Version	Date	Major contributors	Highlights
Prototype 1	1995	Ginsburg, Bak, Kiene, Gischler and Kosmynin. (1996)	Large stony corals–mortality and size quantified in Florida Keys
Prototype 2	1996-1997	Steneck and Lang	Initial draft of AGRRA benthos and fish protocols prepared and field-tested in the Bahamas and Mexico
Prototype 3	Summer 1997	Kramer, Kosmynin, Marks, and Kramer	First extensive field test and consistency training in Florida Keys and Andros; Benthos protocol–damselfish and sources of coral mortality added; Fish protocol–Roving Diver Technique used in addition to belt transects
Version 1.0	Fall 1997	Steneck, Lang, Kramer & Ginsburg	First version posted at AGRRA web site
Version 2.0	June 1998	Ginsburg, Kramer, Lang, Sale and Steneck	Revised on basis of Miami June 1998 Workshop: Benthos protocol–estimates of live stony coral cover added, bleaching categories defined, placement of algal quadrats and substratum type standardized, macroalgal height changed from maximum to average; Fish protocol–belt transects and Roving Diver Technique methods adopted, belt transect length and number stabilized at 30 m and 10, respectively
Version 2.1	March 1999	Bonaire Training Workshop	Benthos protocol–minimum size for individual stony coral assessment informally changed from 25 cm to 10 cm, coral disease terminology standardized; Fish protocol–parrotfish and grunts <5 cm in total length removed; UW data sheets standardized; Excel data spreadsheets introduced
Version 2.2	May 1999	Akumal Training Workshop	Benthos protocol–informal clarification that thin layers of sediment only should be removed from substratum in algal quadrats; Fish protocol–species in “Other” category of belt transects standardized; First Spanish translation of workshop training manual

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Table 1 Continued.

Version	Date	Major contributors	Highlights
Version 3.0	May 2000		<p>Revised on basis of Miami May 2000 Workshop:</p> <p>Benthos protocol—minimum number of transects set at 6, minimum size for individual stony corals changed from 25 cm to 10 cm and minimum number of colonies assessed changed from 100 to 50, minimum number of quadrats changed from 50 to 30, turf algae removed and macroalgae partitioned into fleshy and calcareous with separate measurements of their average heights, relative abundance of remaining algal functional groups redefined to be assessed without removal of canopy layers or sediment, coral recruit counts changed from optional to required, a measure of maximum reef relief added;</p> <p>Fish protocol—species of balistids and serranids in belt transects standardized</p>

Table 2. List of stony corals surveyed in the AGRRA belt transects during 1997-2000.

Suborder Family ¹	Species ¹
Milleporina Milleporidae	<i>Millepora alcicornis</i> <i>M. brazilienses</i> ² <i>M. complanata</i>
Scleractinia	
Acroporidae	<i>Acropora cervicornis</i> <i>A. palmata</i> <i>A. prolifera</i>
Agaricidae	<i>Agaricia agaricites</i> <i>A. fragilis</i> <i>A. grahamae</i> <i>A. humilis</i> <i>A. lamarcki</i> <i>A. tenuifolia</i> <i>A. undata</i> <i>Leptoseris cucullata</i>
Astrocoeniidae	<i>Stephanocoenia intersepta</i>
Caryophyllidae	<i>Eusmilia fastigiata</i>
Faviidae	<i>Colpophyllia natans</i> (OR <i>C. amaranthus</i> , <i>C. breviserialis</i> and <i>C. natans</i>) <i>Cladocora arbuscula</i> <i>Diploria clivosa</i> <i>D. labyrinthiformis</i> <i>D. strigosa</i> <i>Favia fragum</i> <i>F. leptophylla</i> ² <i>Manicina areolata</i> <i>Montastraea annularis</i> (OR <i>Montastraea annularis f. annularis</i>) <i>M. cavernosa</i> <i>M. faveolata</i> (OR <i>Montastraea annularis f. faveolata</i>) <i>M. franksi</i> (OR <i>Montastraea annularis f. franksi</i>) <i>Solenastrea bournoni</i> <i>S. hyades</i>
Meandrinidae	<i>Dendrogyra cylindrus</i> <i>Dichocoenia stokesi</i> <i>Meandrina meandrites</i>
Mussidae	<i>Isophyllastrea rigida</i> <i>Isophyllia sinuosa</i> <i>Mussa angulosa</i> <i>Mussismilia braziliensis</i> ² <i>M. hartii</i> ² <i>M. hispida</i> ² <i>Mycetophyllia aliciae</i> <i>M. ferox</i> <i>M. lamarckiana</i> (OR <i>M. danaana</i> and <i>M. lamarckiana</i>)

Table 2 Continued.

Suborder Family ¹	Species ¹
	<i>Scolymia cubensis</i>
	<i>S. lacera</i>
Oculinidae	<i>Oculina</i> sp.
Pocilloporidae	<i>Madracis decactis</i>
	<i>M. formosa</i>
	<i>M. mirabilis</i>
	<i>M. pharensis</i>
Poritidae	<i>Porites astreoides</i>
	<i>P. branneri</i>
	<i>P. furcata</i> (OR <i>P. porites</i> f. <i>furcata</i>)
	<i>P. porites</i> (OR <i>P. porites</i> f. <i>porites</i>)
Siderastreidae	<i>Siderastrea radians</i>
	<i>S. siderea</i> (OR <i>Siderastrea radians</i> f. <i>siderea</i>)
	<i>S. stellata</i> ²

¹ Family and species names as in Cairns et al. (1991), except for Foster's (1987) revision of *Stephanocoenia*, and Weil and Knowlton's (1994) revision of the *Montastraea annularis* species complex.

² in Brazil

Table 3. List of fishes surveyed in the AGRRA belt transects (Version 2.2).

Family names ¹		Species names ¹	
Scientific	Common	Scientific	Common
Acanthuridae	surgeonfish	<i>Acanthurus bahianus</i>	ocean surgeonfish
		<i>A. chirurgus</i>	doctorfish
		<i>A. coeruleus</i>	blue tang
Balistidae	leatherjackets	<i>Aluterus scriptus</i>	scrawled filefish
		<i>B. vetula</i>	queen triggerfish
		<i>Cantherhines macrocerus</i>	whitespotted filefish
		<i>C. pullus</i>	orangespotted filefish
		<i>C. sufflamen</i>	ocean triggerfish
		<i>Melichthys niger</i>	black durgon
		<i>Xanthichthys ringens</i>	Sargassum Triggerfish
Chaetodontidae	butterflyfish	<i>Chaetodon aculeatus</i>	longsnout butterflyfish
		<i>C. capistratus</i>	four-eye butterflyfish
		<i>Chaetodon ocellatus</i>	spotfin butterflyfish
		<i>Chaetodon sedentarius</i>	reef butterflyfish
		<i>Chaetodon striatus</i>	banded butterflyfish
Haemulidae ²	grunt	<i>Anisotremus surinamensis</i>	black margate
		<i>A. virginicus</i>	porkfish
		<i>Haemulon album</i>	margate
		<i>H. aurolineatum</i>	tomtate
		<i>H. carbonarium</i>	caesar grunt
		<i>H. chrysargyreum</i>	smallmouth grunt
		<i>H. flavolineatum</i>	French grunt
		<i>H. macrostomum</i>	Spanish grunt
		<i>H. melanurum</i>	cottonwick
		<i>H. parra</i>	sailors choice
		<i>H. plumieri</i>	white grunt
		<i>H. sciurus</i>	bluestriped grunt
		<i>H. striatum</i>	striped grunt
Lutjanidae	snapper	<i>Lutjanus analis</i>	mutton snapper
		<i>L. apodus</i>	schoolmaster
		<i>L. cyanopterus</i>	cupera snapper
		<i>L. griseus</i>	gray snapper
		<i>L. jocu</i>	dog snapper
		<i>L. mahogoni</i>	mahogany snapper
		<i>L. synagris</i>	lane snapper
		<i>Ocyurus chrysurus</i>	yellowtail snapper
Pomacanthidae	angelfish	<i>Centropyge argi</i>	cherubfish
		<i>Holacanthus bermudensis</i>	blue angelfish
		<i>H. ciliaris</i>	queen angelfish
		<i>H. tricolor</i>	rock beauty
		<i>Pomacanthus arcuatus</i>	gray angelfish
		<i>P. paru</i>	French angelfish

Table 3 Continued.

Family names ¹		Species names ¹			
Scientific	Common	Scientific	Common		
Scaridae ²	parrotfish	<i>Scarus coelestinus</i>	midnight parrotfish		
		<i>S.coeruleus</i>	blue parrotfish		
		<i>S. croicensis</i>	striped parrotfish		
		<i>S. guacamaia</i>	rainbow parrotfish		
		<i>S. taeniopterus</i>	princess parrotfish		
		<i>S. trispinosus</i> ³	greenlip parrotfish		
		<i>S. vetula</i>	queen parrotfish		
		<i>Sparisoma atomarium</i>	greenblotch parrotfish		
		<i>S. aurofrenatum</i>	redband parrotfish		
		<i>S.chrysopterus</i>	redtail parrotfish		
		<i>S. radians</i>	bucktooth parrotfish		
		<i>S. rubripinne</i>	redfin parrotfish		
		<i>S. viride</i>	stoplight parrotfish		
		Serranidae	sea basses (grouper)	<i>Epinephelus adscensionis</i>	rock hind
				<i>E. cruentatus</i>	graysby
<i>E. fulvus</i>	coney				
<i>E. guttatus</i>	red hind				
<i>E. marginatus</i> ³	dusky grouper				
<i>E. striatus</i>	Nassau grouper				
<i>Mycteroperca bonaci</i>	black grouper				
<i>M interstitialis</i>	yellowmouth grouper				
<i>M. rubra</i>	comb grouper				
<i>M. tigris</i>	tiger grouper				
Others		<i>M. venenosa</i>	yellowfin grouper		
		<i>Bodianus rufus</i>	spanish hogfish		
		<i>Caranx ruber</i>	bar jack		
		<i>Lachnolaimus maximus</i>	hogfish		
		<i>Microspathodon chrysurus</i>	yellowtail damselfish		
		<i>Sphyraena barracuda</i>	great barracuda		

¹Nomenclature as in Robbins et al. (1991); see Appendix Two for the corresponding generic and specific names in Eschmeyer et al. (1998).

² Excluding Haemulidae and Scaridae <5 cm in total length.

³ in Brazil