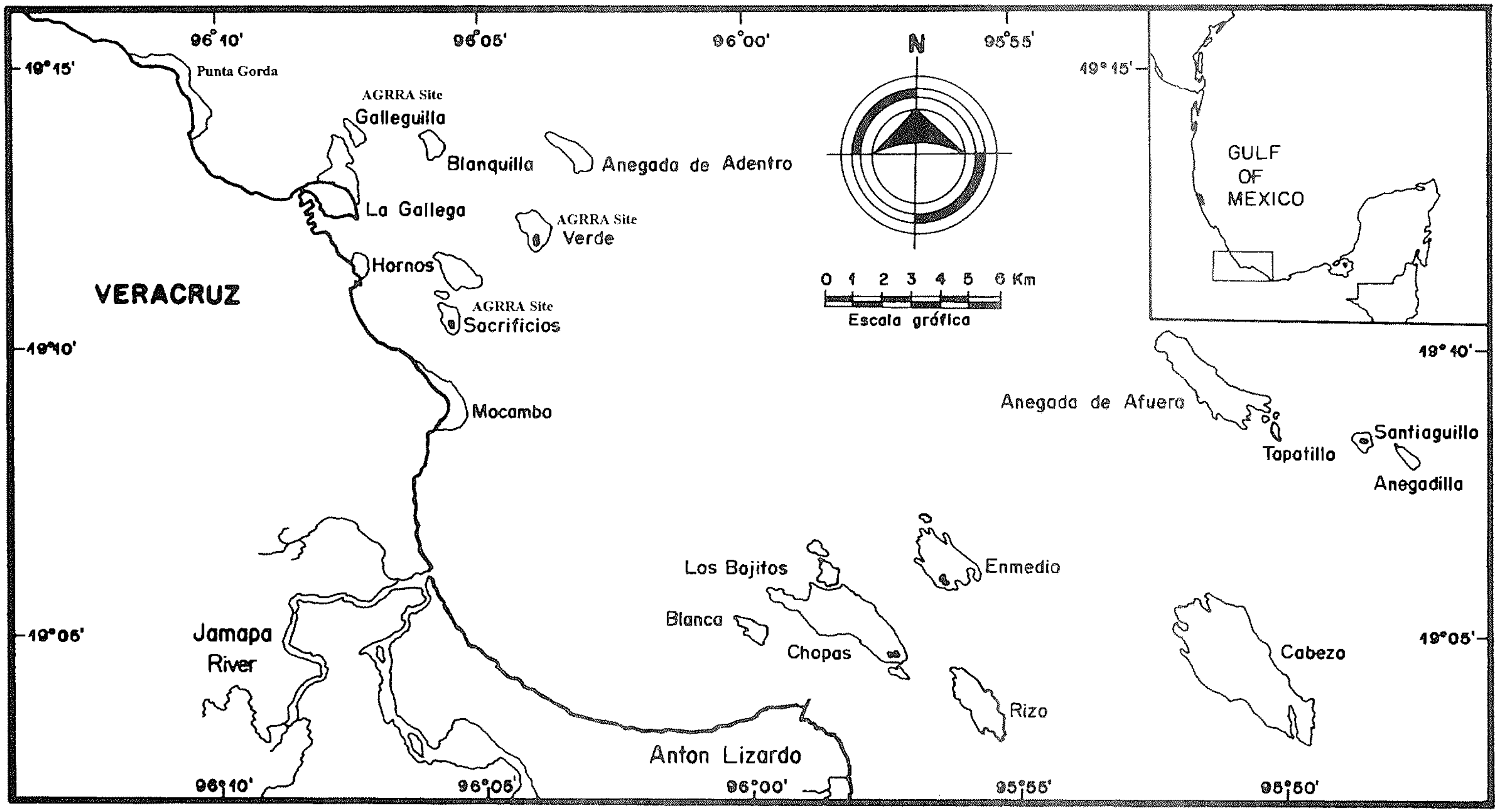

Figure 1. AGRRA survey sites in the Veracruz Reef System.

CONDITION OF SELECTED REEF SITES IN THE VERACRUZ REEF SYSTEM (STONY CORALS AND ALGAE)

BY

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ABSTRACT

Three platform reefs off the city of Veracruz in the Gulf of Mexico were surveyed during July, 1999 with the Atlantic and Gulf Rapid Reef Assessment (AGRRA) benthos protocols at two depth intervals (3-6 m and 9-12 m) in windward fore-reef habitats. Live stony coral cover averaged 17%. Biodiversity was low with 15 taxa of "large" (≥25 cm diameter) stony corals of which *Montastraea cavernosa* was numerically the most abundant (35%). Acroporids were almost completely absent. The condition of the large living corals was good with few signs of disease (none in the individually assessed colonies) and little bleaching. Crustose coralline algae were more abundant overall than turf algae while marcoalgae were scarce. As coral recruitment density was extremely low (~1.2 recruits/m^2), the current potential for recovery of these reefs to historical levels of live coral cover seems poor, even though apparently suitable recruitment sites were available in most sites.

INTRODUCTION

The 20 coral reefs of the Veracruz Reef System (VRS) are located within 22 km of the coast near the Port of Veracruz in the western Gulf of Mexico (Fig. 1). The reefs developed on the continental shelf after the last glacial period some 9,000 to 10,000 years ago (Morelock and Koenig 1967; Kühlmann 1975). They have thrived in a naturally turbid environment. Visibility can be <1 m during the rainy season (June-October) when high concentrations of suspended particles (eroded materials from the mainland) are transported by several rivers (Antigua, Jamapa, Papaloapan) that discharge nearby. The area is also affected by several cold fronts each winter that decrease seawater temperature and increase surf and turbidity.

The VRS reefs have well-developed reef frameworks (Carricart-Ganivet et al., 1993). The windward fore-reef slopes, which face east and north, have the highest stony coral cover and extend to depths of about 30 m (Gutierrez et al., 1993; Vargas-Hernández et al., 1993). Live stony coral cover is lower, and limited to depths of about 21 m, on the leeward (westward-facing) slopes which, however, have the highest diversity of scleractinians as certain ramose and delicate species only occur in these areas. The reef flats (also called platforms or lagoons) are well-illuminated, shallow (1.0-1.6 m in depth), and dominated by

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macroalgae, the seagrass, *Thalassia testudinum*, and some stony corals. The reef crests or rubble ramparts, which are located at the windward margins of the reef flats, are accumulations of dead coral boulders deposited by strong storm waves and currents (Kühlmann, 1975; Gutierrez et al., 1993).

As in other remote Atlantic reef areas like the Flower Garden Banks and Bermuda, the diversity of reef-building scleractinians is relatively depauperate with 30 zooxanthellate species in the VRS in contrast to the 47 found on Mexican Caribbean reefs in the eastern Yucatan Peninsula (Horta-Puga and Carricart-Ganivet, 1993; Beltrán-Torres and Carricart-Ganivet, 1999; Ruiz et al., this volume). Historically, the main species have been *Acropora cervicornis*, *A. palmata*, *Diploria clivosa*, *D. strigosa*, *Siderastrea radians*, *S. siderea*, *Montastraea annularis*, *M. cavernosa*, *M. faveolata* and *Colpophyllia natans* (Lara et al., 1992; Gutierrez et al., 1993). However, both species of *Acropora* experienced widespread mortality during the 1970s-1980s (Jordán, 1992; Tunnell, 1992), possibly at least in part from disease. At present the bottom is dominated by the long-dead skeletons of important genera (*Acropora, Montastraea, Colpophyllia, Diploria, Siderastrea)* which are still recognizable suggesting high mortality rates in recent decades. Populations of *Diadema antillarum* were possibly decimated during the 1983-84 mass mortality event which changed sea-urchin community structure throughout the Western Atlantic. Nowadays, species of *Echinometra* (*E. lucunter* and *E. viridis)* are among the most abundant herbivores in the VRS (see Results).

The reefs of the VRS have been considered to be among the most threatened in the wider Caribbean. Anthropogenic impacts in the area are diverse and include oil spills plus other chemical pollutants, overfishing, unrestricted recreational diving, ship groundings, sewage effluents, dredging, recreational diving, and boat anchoring (Tunnell, 1992; Lang et al., 1998). Environmental stressors have increased in magnitude in recent decades. In response to scientific concern, the entire VRS was decreed a marine protected area by the Mexican Government in 1992 (Diario Oficial, 1992). In 2000, the National Commission of Natural Protected Areas designated the staff of the marine park who are now actively developing a management plan as well as performing surveillance and conservation activities.

The aim of this study was to assess the current condition of the VRS using the AGRRA benthos protocols.

METHODS

The VRS is divided into a northern and a southern group by the outlet of the Jamapa River. The northern group has three coastal fringing reefs and seven platform reefs rising 25-30 m above the bottom (Carricart-Ganivet and Horta-Puga, 1993). Three platform-type mid-shelf reefs (Fig. 1) were chosen to assess the benthic condition of the northern VRS reef system. Galleguilla was strategically chosen because it is considered highly threatened due to its position near the outlet of Veracruz City's sewage treatment plant and the port docks. Isla Verde, which is furtherest offshore, and Isla de Sacrificios are both considered representative platform reefs. The latter is also a strategic site because its reef has been closed to all human activities related to tourism or fishing by local authorities since 1982 and was hoped to be in a process of recovery after having been highly degraded. The surveys were conducted in windward (eastern), fore-reef slope habitats. Two depth zones were selected: the shallow (3-6

m) former *Acropora* zone and a deeper (9-12 m) zone of maximum scleractinian diversity and coverage.

The AGRRA Version 2 benthos protocols (see Appendix One, this volume) were followed from 14-22 July 1999 with the following modifications: (1) colonies that were "standing dead" (completely dead and still in growth position) were not surveyed, i.e., individual assessments were restricted to "large" (≥25 cm maximum diameter) corals with at least some living tissues; (2) coral measurements were made to the nearest 5 cm; (3) *Diploria*, *Siderastrea* and *Agaricia* were identified only to the genus level; and (4)*Echinometra* (*E. lucunter* + *E. viridis*) counts were added to the belt transects in all but the deep Isla de Sacrificios site. As the surveys were performed during the local rainy season, water turbidity was high. Visibility at any depth was usually <5 m, and often <2 m. In order to standardize the data, we spent a day assessing the same transects and quadrats until all team members consistently recorded similar results.

RESULTS

Stony Corals

A team of seven divers (four divers/dive) surveyed 723 large (≥25 cm in diameter), living stony corals, examined 662 quadrats, and conducted 138 live stony coral cover transects plus 124 belt transects for sea urchin abundance. Live stony coral coverage varied from 15% in Galleguilla to 21% in Isla de Sacrificios, averaging 17% overall (Table 1). The remaining substratum mostly consisted of coral skeletons that were moderately intact to highly eroded.

We recorded 14 taxa of large living scleractinians and one hydrozoan (Table 2). The total number of taxa per reef varied from 6 in Galleguilla to 14 in Isla de Sacrificios, and from 12 in the deeper zones to 13 in the shallow zones. In terms of numerical abundance, *Montastraea cavernosa* was the predominant large species (overall mean = 35%), dominating both depths in Isla de Sacrificios and the shallow Galleguilla transects. *Colpophyllia natans* was the second most common overall (26.5%) and dominated both depths in Isla Verde. *Siderastrea* was the most common large taxon in the deep Galleguilla site. Depth had relatively little effect on mean numerical abundance with *M. cavernosa* > *C. natans* > *Diploria* > *Siderastrea* in the three shallow zones, and *M. cavernosa* > *C. natans* > *Siderastrea* > *Diploria* in the three deeper zones.

The average numbers of large living stony corals per 10 m transect varied from 5 in Galleguilla and Isla Verde to 6.5 in Isla de Sacrificios (Table 1). Their mean size (as maximum diameter) overall was 59 cm (Table 3). Bleached or partially bleached corals accounted for 3% of the overall total. Black-band disease (in *Siderastrea*, *Montastraea* spp.), tumor neoplasms (in *Diploria*) and dark spots disease (in *Siderastrea*) were seen in the VRS during the survey but no diseases were found in any of the surveyed corals.

Recent partial-colony mortality (hereafter recent mortality) of the large live stony corals averaged <1% of their upward-facing surfaces in five sites and was greatest (mean = 3%) in the shallow Isla de Sacrificios site. The percentage of affected corals varied from 0 to 13%, averaging 4% overall (Table 3). Average values for old partial-colony mortality (hereafter old mortality) varied between 6.5% at Galleguilla shallow and 13% at Isla Verde shallow, with over 40% of all colonies having areas of old tissue loss. Trends in total (recent + old) mortality were similar to those for old mortality.

Coral recruitment averaged 0.1/0.0625 m^2 ($\sim$1.2/m^2) and was low in all sites (Table 4). Sixty-seven recruits were counted: the numbers/taxa (and percent of total) were *Siderastrea* 43 (64%), *Oculina* 12 (18%), *Porites* and *Agaricia* 3 each (4%), *M. annularis* and *C. natans* 2 each (3%), *S. intersepta* and *M. complanata* 1 (1%) each.

Algae and Echinoids

In general, crustose coralline algae (overall absolute abundance = 41%), followed by turf algae (overall absolute abundance = 26.5%), dominated the algal quadrats; however, turf algae were somewhat more abundant than crustose corallines at both depths off Galleguilla (Table 4). Macroalgae were notably scanty in the VRS fore-reef zones (overall absolute abundance = 0.5%) and, as their mean height was <1 cm, the absolute macroalgal index (macroalgal abundance x macroalgal height) was approximated as 0 to <1. On average, "barren areas" covered with sediment (terrigenous + endogenous) and lacking conspicuous sessile organisms occupied 13.5% of the substrata and, at the Isla de Sacrificios deeper site, they dominated the available substratum (60%).

Although present in the VRS, only two specimens of *Diadema antillarum* were seen during the survey and none were counted in the belt transects. Densities of *Echinometra* varied between 10/100m^2 in the deep Galleguilla site and 155/100 m^2 in the shallow Isla de Sacrificios site, averaging 65/100m^2 overall (Table 4).

DISCUSSION

Live stony coral cover was much higher during the mid 1960´s when Kühlmann (1975) recorded values of 50% in shallow and 40% in deep areas, respectively, of Blanquilla reef. At that time, *Acropora. palmata* covered up to 65% of the available substrata in some shallow VRS reefs and the cover of *A.cervicornis* reached 100% in Enmedio reef (Ranefeld, 1972; Kühlmann, 1975). Live *Acropora* spp. accounted for <1.5% of the stony coral cover at 3-6 m in 1999. Overall, our data indicate that the VRS reefs had changed little since Tunnell's (1992) report on their condition when coral cover was 17% and 12% in the fore reefs at Enmedio and Cabezo Reefs, respectively. The reduced coral cover in the VRS reefs is a clear indication of serious ecosystem decline, even when it is recognized that nowadays an average of 17% is fairly typical of many Caribbean reef areas (see Kramer, this volume).

That the VRS mortality estimates for colony surfaces in large (≥25 cm diameter) stony corals are low (especially for old mortality) in comparison to data collected elsewhere in the western Atlantic (Kramer, this volume) is partially explicable by our exclusion of standing dead corals from these assessments. Nevertheless, in spite of the scarcity of coral diseases and the relatively high availability of crustose coralline algae as a substratum for larval settlement (Morse et al., 1994), the chances for significant recovery of the VRS fore-reef communities seem poor so long as coral recruitment, especially by the broadcasting species that are so important in reef framework construction, is low.

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Table 1. Site information for AGRRA stony coral and algal surveys off Veracruz, México.

Reef name	Site code	Reef type[1]	Latitude (° ' " N)	Longitude (° ' " W)	Survey date(s)	Depth (m)	Benthic Transects (#0	≥25 cm live stony corals (#/10 m)[2]	% livestony coral cover (mean ± sd)[2]
Shallow									
Galleguilla	GA3	Wind fore	19 13 53	96 07 37	July 20-22 99	3-6	24	4.5	16.0 ± 11.5
Isla de Sacrificios	IS3	Wind fore	19 10 26	96 05 32	July 18-19 99	3-6	22	7.0	19.5 ± 22.5
Isla Verde	IV3	Wind fore	19 11 50	9604 06	July 15 99	3-6	28	4.0	14.5 ± 9.0
All shallow	**VR 3**					**3-6**	**74**	**5.0**	**16.5 ± 15.0**
Deeper									
Galleguilla	GA9	Wind fore	19 13 53	96 07 37	July 19-20 99	9-12	24	5.0	14.0 ± 8.0
Isla de Sacrificios	IS9	Wind fore	19 10 26	96 05 32	July 16-17 99	9-12	19	5. 5	22.5 ± 15.0
Isla Verde	IV9	Wind fore	19 11 50	96 04 06	July 14-16 99	9-12	21	6.0	18.5 ± 8.0
All deeper	**VR 9**					**9-12**	**64**	**5.5**	**18.0 ± 11.0**
All Galleguilla	**All GA**					**3-6; 9-12**	**48**	**5.0**	**15.0 ± 10.0**
All Isla de Sacrificios	**All IS**					**3-6; 9-12**	**41**	**6.5**	**21.0 ± 19.5**
All Isla Verde	**All IV**					**3-6; 9-12**	**49**	**5.0**	**16.0 ± 8.0**
All sites	**All VR**					**3-6; 9-12**	**138**	**5. 0**	**17.0 ± 13. 5**

[1]Wind = windward
[2]Standing dead corals were not surveyed.

Table 2. Relative abundance and species richness of all live[1] stony corals (≥25 cm diameter) by site off Veracruz, México.

Species	Galleguilla %		Isla de Sacrificios %		Isla Verde %		All Reefs %		
	3-6 m	9-12 m	3-6 m	9-12 m	3-6 m	9-12 m	**3-6m**	**9-12 m**	**Both depths**
M. alcicornis		1.0	3.5		1.0	1.0	**1.5**	**0.5**	**1.0**
A. cervicornis						1.0		0.5	<0.5
A. palmata			1.5		9.0		**3.0**		**1.5**
Agaricia spp.			0.5	2.0			**0.5**	**0.5**	**0.5**
C. natans	20.5	10.0	12.5	9.0	50.0	60.0	**25.5**	**27.5**	**26.5**
Diploria	4.5	1.0	19.5	5.0	23.0	18 0	**16.0**	**8.5**	**12.5**
M. decactis			0.5				**0.5**		<0.5
M. annularis				6.0	5.5	4. 5	**1.5**	**3.5**	**2.5**
M. cavernosa	59.5	30.0	49.0	56.0	7.5	8. 5	**40.0**	**29 5**	**35.0**
M. faveolata				6.0	2.0	1.0	**0.5**	**2/0**	**1.0**
M. franksi				1.0				**0.5**	<0.5
O. diffusa			0.5				**0.5**		<0.5
P. astreoides			2.0			1.0	**1.0**	**0.5**	**0.5**
Siderastrea	13.5	58.5	10.5	11.0	3.0	4. 5	**9.0**	**25.5**	**17.0**
S. intersepta	2.0			4.0		1.0	**0.5**	**1.5**	**1.0**
All taxa (#)	**5**	**5**	**10**	**9**	**8**	**10**	13	12	15

[1]Standing dead corals were not surveyed.

Table 3. Size and condition (mean ± standard deviation) of all live[1] stony corals (≥25 cm diameter) by site off Veracruz, México.

Site code[2]	Live stony corals		Partial-colony mortality of live stony corals (%)			Live stony corals (%)				
	#	Diameter (cm)	Recent	Old	Total	Recent mortality	Old mortality	Total mortality	Bleached	Diseased
Shallow										
GA3	111	67 ± 33	<0.5 ± 1.0	6.5 ± 11.5	6.5 ± 11.5	1.0	34.0	35.0	2.0	0
IS3	153	53 ± 34	3.0 ± 9.0	7.0 ± 13.0	10.0 ± 14.5	13.0	35.5	48.5	4.5	0
IV3	109	59 ± 23	0.5 ± 3.5	13.0 ± 18.0	13.5 ± 18.0	3.5	55.0	58.5	0	0
All VR 3	**373**	**59 ± 31**	**1.5 ± 6.5**	**7.0 ± 12.0**	**8.5 ± 13.5**	6.5	41.0	47.5	**2.5**	**0**
Deeper										
GA9	123	53 ± 28	0	9.0 ± 12.0	9.0 ± 12.0	0	49.0	49.0	5.5	0
IS9	100	75 ± 65	<0.5 ± 1.0	11.5 ± 17.0	11.5 ± 17.0	1.0	43.0	44.0	1.0	0
IV9	127	52 ± 22	<0.5 ± 4.0	6.5 ± 11.5	7.0 ± 12.0	3.0	36.0	39.5	2.5	0
All VR 9	**350**	**59 ± 42**	**<0.5 ± 2.5**	**9.5 ± 14.0**	**9.5 ± 14.0**	1.5	42.5	44.0	**3.0**	**0**
All GA	**234**	**59 ± 31**	**<0.5 ± 0.5**	**8.0 ± 12.0**	**8.0 ± 12.0**	0.5	42.0	42.5	**4.0**	**0**
All IV	**236**	**55 ± 53**	**0.5 ± 3.5**	**9.5 ± 15.0**	**10.0 ± 15.5**	3.5	45.0	48.5	**1.5**	**0**
All IS	**253**	**61 ± 50**	**2.0 ± 7.5**	**9.0 ± 14.5**	**10.5 ± 15.5**	8.5	38.5	46.5	**3.0**	**0**
All VR	**723**	**59 ± 37**	**<0.5 ± 0.5**	**8.5 ± 12.5**	**8.5 ± 12.5**	4.0	41.5	46.0	**3.0**	**0**

[1]Standing dead corals were not surveyed.
[2].See Table 1 for site codes.

Table 4. Algal characertistics, density of sessile invertebrates, sediment, stony coral recruits and echinoderms (mean ± standard deviation) by site off Veracruz, México.

Site code[1]	Quadrats (#)	Absolute abundance (%)					Macroalgae		Recruits (#/.0625 m²)	Echinoid transects (#)	*Echinometra* (#/100 m²)	*Diadema* (#/100 m²)
		Macroalgae	Turf algae	Crustose Coralline algae	Sessile Invertebrates	Sediment	Height (cm)	Index[2]				
VR 3												
GA3	105	0	36.5 ± 27.0	32.0 ± 20.5	28.5 ± 23.0	3.5 ± 9.0		0	0.2 ± 0.4	28	62 ± 30	0
IS3	117	1.0 ± 8.5	23.0 ± 20.0	37.5 ± 24.5	26.5 ± 24.0	12.0 ± 22.0	<1.0	<1	0.0 ± 0 .1	27	155 ± 154	0
IV3	140	0	19.5 ± 20.0	56.5 ± 35.5	18.0 ± 19.0	9.5 ± 18.0		0	0.0 ± 0.2	21	25 ± 39	0
All VR 3	**362**	**<0.5**	**25.5 ± 23.5**	**43.0 ± 30.0**	**24.0 ± 22.0**	**8.5 ± 18.0**	**<1.0**	**<0.5**	**0.1 ± 0.2**	**76**	**79 ± 107**	**0**
VR 9												
GA9	115	1.0 ± 6.0	49.5 ± 17.5	37.5 ± 16.0	9.5 ± 9.5	0.5 ± 6.5	<1.0	<1	0.1 ± 0.3	21	10 ± 16	0
IS9	80	0	13.0 ± 18.0	14.5 ± 18.5	13.5 ± 15.0	60.0 ± 36.0		0	0.1 ± 0 .3	ND[3]	ND	0
IV9	105	0	15.5 ± 22.5	26.5 ± 31.5	19.0 ± 25.0	10.0 ± 16.5		0	0.0 ± 0.2	24	72 ± 86	0
All VR 9	**300**	**0.5 ± 5.0**	**28.0 ± 26.0**	**39.0 ± 28.5**	**14.0± 18.0**	**19.5 ± 26.0**	**<1.0**	**0.5**	**0.1 ± 0.3**	**45**	**39 ± 67 (2 sites)**	**0**
All GA	**220**	**0.5 ± 4.0**	**43.5 ± 23.5**	**36.0 ± 18.5**	**18.5 ± 19.5**	**1.5 ± 6.0**	**<1.0**	**0.5**	**0.1 ± 0.4**	**49**	**34 ± 36**	**0**
All IS	**197**	**0.5 ± 6.5**	**19.0 ± 20.0**	**28.0 ± 25.0**	**21.5 ± 21.5**	**31.5 ± 37.0**	**<1.0**	**0.5**	**0.0 ± 0.2**	**ND**	**ND**	**0**
All IV	**245**	**0.5 ± 4.0**	**17.5 ± 21.0**	**56.5 ± 33.5**	**18.5 ± 22.0**	**9.5 ± 17.5**	**0**	**0**	**0.0 ± 0.2**	**45**	**45 ± 67**	**0**
All VR	**662**	**0.5 ± 5.0**	**26.5 ± 24.5**	**41.0 ± 29.5**	**19.5 ± 21.0**	**13.5 ± 26.0**	**<1.0**	**0.5**	**0.1 ±0 .3**	**124**	**63 ± 96 (8 sites)**	**0**

[1] See Table 1 for site codes.
[2] Macroalgal index = absolute macroalgal abundance x macroalgal height
[3] ND = not done