Fish and Coral Reef Communities of the Parque Nacional Sistema Arrecifal Veracruzano (Veracruz Coral Reef System National Park) Veracruz, Mexico: Preliminary Results

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ABSTRACT

Effective resource management requires robust baseline datasets and efficient monitoring programs to identify and quantify temporal change. The Parque Nacional Sistema Arrecifal Veracruzano (Veracruz Coral Reef System National Park) encompasses a total of 52000ha including 23 coral reefs in two island groups separated by the mouth of the Jamapa River; one near the port of Veracruz, Mexico and one approximately 20km south near Punta Antón Lizardo. Both groups receive substantial fisheries pressure and other anthropogenic impacts. Using non-destructive, visual methods we surveyed fish and benthic assemblages at 18 sites, which included 10 individual coral reefs within the Park. For fishes, 221 point-count and 97 rover-diver surveys were conducted. In total, 92975 fish of 155 species were recorded. Using point-count data, fish abundance differed between Veracruz and Antón Lizardo sites (mean ± SEM: Veracruz = 535.52 ± 78.13; Antón Lizardo = 300.08 ± 30.68; $p<0.01$, ANOVA). In contrast, there was no difference in fish species richness between these sites (Veracruz = 18.22 ± 0.36; Antón Lizardo = 18.75 ± 0.45); nor were there apparent differences in the MDS plot of Bray-Curtis similarity indices. A total of 27 stony coral species was identified on 170, 30-m point-intercept transects. Species richness ranged from 8 to 14 per site. Stony coral cover ranged from 4% to 38% with a mean of 22%. Other important functional groups included turf algae, macroalgae, and coralline algae. These groups generally contributed more to benthic cover than sponges or octocorals. Evidence of disease within the stony coral community was seen at all sites.

KEY WORDS: vFish, coral reef, Veracruz, Mexico

Comunidades de Peces y Corales en el Parque Nacional Sistema Arrecifal Veracruzano (Veracruz Coral Reef System National Park) Veracruz, Mexico: Resultados Preliminares

El manejo efectivo de los recursos requiere de referencias de líneas base firmes y programas de monitoreo eficientes para identificar y cuantificar cambios temporales. El Parque Nacional Sistema Arrecifal Veracruzano (Veracruz Coral Reef System Nacional Park) abarca un total de 52000 hectáreas incluyendo 23 arrecifes coralinos en dos grupos separados por la boca del río Jamapa; uno cercano al puerto de Veracruz, México y el otro a 20km al Sur, cerca de Punta Antón Lizardo. Ambos grupos reciben considerables impactos pesqueros y = otros tipos de impacto antropogénicos. Empleando métodos visuales no destructivos estudiamos las - communidades de peces y bentos en 18 sitios, incluyendo 10 arrecifes coralinos dentro del Parque Nacional. Para peces, fueron realizados 222 conteos de puntos y 97 censos de buceo errante. En total, 92975 peces de 155 especies fueron registrados. Empleando los datos de conteo de puntos, la abundancia de peces difiere entre los sitios de Veracruz y Antón Lizardo (media ± SEM: Veracruz = 535.52 ± 78.13; Antón Lizardo = 300.08 ± 30.68; $p<0.01$, ANOVA). En contraste, no existió diferencia en riqueza de especies de peces entre estos sitios (Veracruz = 18.22 ± 0.36; Antón Lizardo = 18.75 ± 0.45; ni tampoco existieron diferencias aparentes en la matriz MDS de los índices de similaridad de Bray-Curtis. Un total de 27 especies de corales duros fueron identificados en 170 transectos por puntos de intersección, cada transecto de 30 metros. La riqueza de especies oscilo de 8 a 14 por sitio. La cobertura de corales duros abarcó de 4% a 38% con una media de 22%. Otros grupos funcionales importantes incluidos fueron tapete algal, macroalgas, y algas coralinas. Estos grupos generalmente contribuyen mas para la cobertura béntica que las esponjas y octocorales. Evidencias de enfermedades en las comunidades de corales duros fueron observadas en todos los sitios.

PALABRAS CLAVES: vPeces, arrecifes coralinos; Veracruz, México

INTRODUCTION

Effective management of any natural resource requires a baseline survey to determine change related to management efforts, anthropogenic activities, or natural impacts. This is the first in a series of studies aimed at characterizing the coral reef fauna of the National Marine Park in Veracruz, Mexico (Comision Nacional de Areas Naturales Protegidas, Parque Nacional (CONANP), Sistema Arrecifal Veracruzano (SAV).

The Park, established in 1992, was Mexico's first national marine park. It covers a territory of more than 52,000 hectares with approximately 23 coral reefs in two island groups separated by the mouth of the Jamapa River. The first region lies offshore the Port of Veracruz and includes seven reefs. The second area is offshore Punta Antón Lizardo, approximately 20 km southeast of Veracruz, and includes 12 reefs. There are also at least seven artificial reefs (sunken vessel reefs) within the Park in less than 30 m of water. The reefs, judged among the most threatened in the Wider Caribbean, receive substantial freshwater discharge from major river systems, which carry heavy sediment, agricultural, and industrial sewage loads. Further anthropogenic impacts include ship groundings, oil spills, port construction, and heavy fishing pressure (Tunnell 1992, Jordán-Dahlgren and Rodríguez-Martínez 2003). From a research standpoint, the Veracruz Reef System represents a coral reef environment with, apparently, little connectivity to other Caribbean reef systems and a unique temperature and salinity regime (Tunnell 1992, Jordán-Dahlgren 2002). Although some Loop Current eddies may reach it on occasion, this area appears to lie outside a direct current connection with the reefs of the Yucatan or other areas in the Greater Caribbean. Larval supply would likely come from the Campeche Bank reefs. But presumably, this is infrequent (references see: Jordán-Dahlgren 2002, Gyory *et al.* 2005). Thus not surprisingly, several fish species new to science have recently been recorded from the area (Taylor and Atkins 2007, D. Weaver Pers. comm.).

Although there have been several previous studies in the area, SAV lacks an inventory or even a full species list of the fishes or corals within the Park (Tunnell 1988, Lara *et al.* 1992, Jordán-Dahlgren 2002, Horta-Puga 2003). Such assessments are critical to both manage the Park as well as to provide an understanding of the resources available for future research. For example, researchers interested in population connectivity among reefs must know the species present to select ideal candidates for analysis. This study represents an initial biological assessment of the Park's fishes and coral community.

METHODOLOGICAL DESIGN/DATA ANALYSIS

General

During April - May 2007, we compared fish and coral assemblages among individual coral reefs within the Park. In order to gain the most insight into structural differences among the species assemblages within the Park, we surveyed six of the northernmost (designated as Veracruz reefs, VR) and five southernmost reefs (Antón Lizardo reefs, ALR), which are separated by more than 20 km of open water (Figure 1). In total, 18 sites were sampled; nine within six Veracruz reefs (Arricefe [A.] Gallega, A. Galleguilla, A. Blanquilla, A. Anegada de Adentro, A. Pajaros, and Isla Verde), and nine within five Antón Lizardo reefs (A. Anegada de Afuera, A. Santiaguillo, A. El Cabezo, A. El Cabezo, and A. Rizo). Previous reports have highlighted windward (North to Northeast) and leeward (South to Southwest) exposure differences in coral assemblages on individual reefs (Lara *et al.* 1992, Horta-Puga 2003). Thus, assessment sites were categorized as Northern exposed (open to the north) and Southern exposed (open to the south) according their GPS locations on a satellite image (Figure 1). This categorization allowed for inference of site energy regimes where no supporting data were available. Site 5 was considered a Southern exposed site because it appeared to be protected by an embayment.

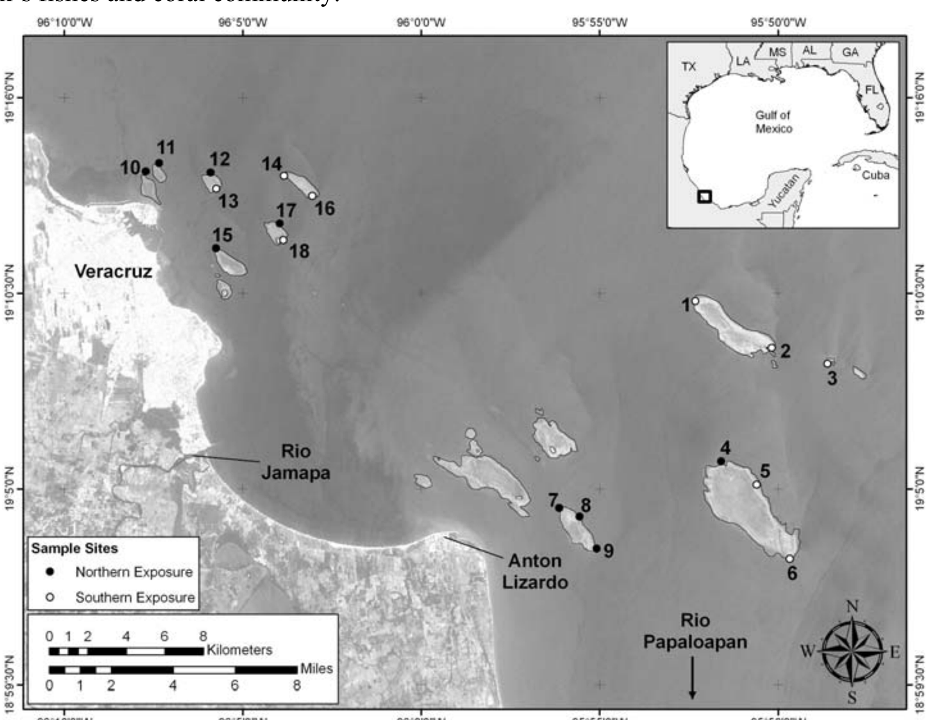

Figure 1. Sample site locations for benthic and fish assessments. The nine north sites comprise the Veracruz group and the nine south sites comprise the Antón Lizardo group. Black dots are the northern exposure sites and white dots have a southern exposure.

Fishes

Fish surveys were conducted using two types of non-destructive, visual surveys: point-counts and rover-diver counts. In the point-count, all species were recorded in an imaginary cylinder, 15 m in diameter, from the substrate to the water surface. A 7.5 m radius line was laid out prior to the count as an aid in estimating the cylinder circumference. For the first five minutes, only species were recorded. After the five minute species count was completed, the abundance of each fish species and its minimum, maximum, and mean total length were recorded. Depth and bottom features were also recorded. The diver accomplished the count by staying in the center of the cylinder and rotating 360° to record species presence, abundance, and lengths. The point-count method has been statistically validated and produces data amenable to rigorous statistical analysis (Bohnsack and Bannerot 1986).

While point-counts provided a means to compare and examine abundance, a major goal of this research was to derive a comprehensive species list of the fishes in the Park using visual census methods. Therefore, because the point-count method can miss cryptic species, we also performed rover-diver counts (Baron *et al.* 2004). This method consists of a diver recording all species encountered during a timed, 20 minute interval. Divers were encouraged to look wherever they please in an attempt to record the maximum number of species present, though no abundance or size data were recorded.

Benthic Assemblage

At 17 of the 18 sites, 10 point-intercept transects of 30m length were sampled (five transects were sampled at Site 13). At each site, an attempt was made to sample five transects at each of two depth ranges (15 - 20 m and 3 - 10 m) for a study total of 35 transect samples. Transects were deployed parallel with the general reef structure with no overlap and with a minimum of 5 m between transects. Benthic community functional group cover was determined by recording the functional group present at every 25 cm point along a 30 m tape for a total of 120 points per transect. The functional groups included: stony coral, gorgonian, sponge, coralline algae, macroalgae, turf algae, and bare substrate (sand or hardbottom). All stony corals were identified to species. The point-intercept transects provided functional group cover estimates, but did not provide information on stony coral condition. At a minimum, the first 10 stony coral colonies along each transect were assessed for additional information on colony condition including: colony size (length X width X height), percent tissue mortality, presence of bleaching, and presence of disease. If less than 10 colonies were present along a transect, all colonies were assessed. The percentage of diseased colonies was obtained by dividing the number of disease occurrences by the total number of colonies assessed at each site. These methods permit direct comparisons to other regional projects (*e.g.,* Horta-Puga 2003) because they were adopted from those used in the Mesoamercian Barrier Reef System Project (Almada-Villela *et al.* 2003) and the widely used Atlantic and Gulf Rapid Reef Assessment (AGRRA 2000).

Data Analysis

Analysis of variance (ANOVA) was used to examine the data for differences in abundance and species richness. In comparisons with >2 categorical predictors, a *post hoc* Newman-Keuls (NK) test was used to determine which predictor(s) significantly differed. Abundance data were log-transformed ($\log_{10}[x + 1]$) prior to analysis to homogenize variance. To examine differences in assemblage structure between regions and exposure categories, non-metric, multi-dimensional scaling (MDS) plots were constructed using Bray-Curtis similarity indices derived from fourth-root transformed abundance data (PRIMER v6). Analysis of similarity (ANOSIM) was used to test if differences in assemblage structure were present between regions, exposure categories, and survey sites. The similarity percentage (SIMPER) analysis was used to identify those species most responsible for the differences seen among different factor groups (Clarke and Gorley 2006).

RESULTS

Fishes

At the 18 sites, 221 point-count and 97 rover-diver surveys were conducted. In total, 92923 fish of 155 species were recorded (Table 1). Using point-count data, fish abundance significantly differed between Veracruz and Antón Lizardo sites (mean ± SEM: VR = 535.52 ± 78.13; ALR = 300.08 ± 30.68; $p < 0.01$, ANOVA). In contrast, no difference in fish species richness between these island groups was found (VR = 18.22 ± 0.36; ALR = 18.75 ± 0.45); nor were there noticeable differences in the MDS plot of Bray-Curtis similarity indices (not shown; ANOSIM R-statistic = 0.083).

Despite apparent homogeneity in fish assemblages illustrated in the MDS plot and the low ANOSIM R-statistic, the SIMPER analysis indicated 82.11% dissimilarity between the VR and ALR sites. More than 62% of the difference between regions was accounted for by six taxa (five species and juvenile *Haemulon* spp.); all planktivores (Table 2). When excluding these taxa from the analysis, the difference present between VR and ALR was reversed, with the highest mean abundance at ALR ($p < 0.05$, ANOVA).

Using point-count data, comparison of fish populations at Northern and Southern exposure sites lacked significant difference in abundance but did differ in species richness, with more mean species at Southern exposure sites (n = 17.87 ± 0.37; S = 19.30 ± 0.46).

Table 1. Fishes recorded from the Parque Nacional Sistema Arrecifal Veracruzano. All sitings included.

Common Name	Scientific Name
NUMBFISHES	**NARCINIDAE**
Lesser electric ray	*Narcine brasiliensis*
STINGRAYS	**DASYATIDAE**
Southern stingray	*Dasyatis americana*
EAGLE AND MANTA RAYS	**MYLIOBATIDAE**
Spotted eagle ray	*Aetobatus narinari*
MORAY EELS	**MURAENIDAE**
Green moray	*Gymnothorax funebris*
Goldentail moray	*Gymnothorax miliaris*
Spotted moray	*Gymnothorax moringa*
Reticulate moray	*Muraena retifera*
LIZARDFISHES	**SYNODONTIDAE**
Sand diver	*Synodus intermedius*
Atlantic lizardfish	*Synodus saurus*
NEEDLEFISHES	**BELONIDAE**
Houndfish	*Tylosurus crocodilus*
SQUIRRELFISHES	**HOLOCENTRIDAE**
Squirrelfish	*Holocentrus adscensionis*
Longspine squirrelfish	*Holocentrus rufus*
Blackbar soldierfish	*Myripristis jacobus*
TRUMPETFISHES	**AULOSTOMIDAE**
Trumpetfish	*Aulostomus maculatus*
SCORPIONFISHES	**SCORPAENIDAE**
Spotted scorpionfish	*Scorpaena plumieri*
SEA BASSES	**SERRANIDAE**
Graysby	*Cephalopholis cruentata*
Rock hind	*Epinephelus adscensionis*
Red hind	*Epinephelus guttatus*
Blue hamlet	*Hypoplectrus gemma*
Shy hamlet	*Hypoplectrus guttavarius*
Black hamlet	*Hypoplectrus nigricans*
Barred hamlet	*Hypoplectrus puella*
Butter hamlet	*Hypoplectrus unicolor*
Comb grouper	*Mycteroperca acutirostris*
Black grouper	*Mycteroperca bonaci*
Yellowmouth grouper	*Mycteroperca interstitialis*
Gag	*Mycteroperca microlepis*
Scamp	*Mycteroperca phenax*
Mottled grouper	*Mycteroperca rubra*
Yellowfin grouper	*Mycteroperca venenosa*
SEA BASSES	**SERRANIDAE**
Creole-fish	*Paranthias furcifer*
Harlequin bass	*Serranus tigrinus*
BASSLETS	**GRAMMATIDAE**
Candy basslet	*Lipropoma carmabi*
BIGEYES	**PRIACANTHIDAE**
Glasseye	*Heteropriacanthus cruentatus*
Bigeye	*Priacanthus arenatus*
CARDINALFISHES	**APOGONIDAE**
Flamefish	*Apogon maculatus*
TILEFISHES	**MALACANTHIDAE**
Sand tilefish	*Malacanthus plumieri*
JACKS	**CARANGIDAE**
Yellow jack	*Carangoides bartholomaei*
Bar jack	*Carangoides ruber*
Blue runner	*Caranx crysos*
Mackerel scad	*Decapterus macarellus*
Round scad	*Decapterus punctatus*
Rainbow runner	*Elagatis bipinnulata*
Greater amberjack	*Seriola dumerili*
Almaco jack	*Seriola rivoliana*
SNAPPERS	**LUTJANIDAE**
Mutton snapper	*Lutjanus analis*
Cubera snapper	*Lutjanus cyanopterus*
Gray snapper	*Lutjanus griseus*
Dog snapper	*Lutjanus jocu*
Mahogany snapper	*Lutjanus mahogoni*
Lane snapper	*Lutjanus synagris*
Yellowtail snapper	*Ocyurus chrysurus*
MOJARRAS	**GERREIDAE**
Yellowfin mojarra	*Gerres cinereus*
GRUNTS	**HAEMULIDAE**
Black margate	*Anisotremus surinamensis*
Porkfish	*Anisotremus virginicus*
White margate	*Haemulon album*
Tomtate	*Haemulon aurolineatum*
Smallmouth grunt	*Haemulon chrysargyreum*
French grunt	*Haemulon flavolineatum*
Spanish grunt	*Haemulon macrostomum*
White grunt	*Haemulon plumierii*
Striped grunt	*Haemulon striatum*
BONNETMOUTHS	**INERMIIDAE**
Boga	*Inermia vittata*
PORGIES	**SPARIDAE**
Sheepshead seabream	*Archosargus probatocephalus*
Seabream	*Archosargus rhomboidalis*
Jolthead porgy	*Calamus bajonado*
Saucereye porgy	*Calamus calamus*
Silver porgy	*Diplodus argenteus*
Spottail pinfish	*Diplodus holbrookii*
DRUMS	**SCIAENIDAE**
Spotted drum	*Equetus punctatus*
Reef croaker	*Odontoscion dentex*
Highhat	*Pareques acuminatus*
GOATFISHES	**MULLIDAE**
Yellow goatfish	*Mulloidichthys martinicus*
Spotted goatfish	*Pseudupeneus maculatus*
SWEEPERS	**PEMPHERIDAE**
Glassy sweeper	*Pempheris schomburgkii*
SEA CHUBS	**KYPHOSIDAE**
Bermuda sea chub	*Kyphosus sectator*
BUTTERFLYFISHES	**CHAETODONTIDAE**
Foureye butterflyfish	*Chaetodon capistratus*
Spotfin butterflyfish	*Chaetodon ocellatus*
Reef butterflyfish	*Chaetodon sedentarius*
ANGELFISHES	**POMACANTHIDAE**
Cherubfish	*Centropyge argi*
Blue angelfish	*Holacanthus bermudensis*
Queen angelfish	*Holacanthus cilaris*
Rock beauty	*Holacanthus tricolor*
Townsend angelfish	*Holacanthus* sp.
Gray angelfish	*Pomacanthus arcuatus*
French angelfish	*Pomacanthus paru*

HAWKFISHES	**CIRRHITIDAE**
Redspotted hawkfish	*Amblycirrhitus pinos*
DAMSELFISHES	**POMACENTRIDAE**
Sergeant major	*Abudefduf saxatilis*
Night sergeant	*Abudefduf taurus*
Blue chromis	*Chromis cyanea*
Sunshinefish	*Chromis insolata*
Brown chromis	*Chromis multilineata*
DAMSELFISHES	**POMACENTRIDAE**
Purple reeffish	*Chromis scotti*
Yellowtail damselfish	*Microspathodon chrysurus*
Dusky damselfish	*Stegastes adustus*
Longfin damselfish	*Stegastes diencaeus*
Beaugregory	*Stegastes leucostictus*
Bicolor damselfish	*Stegastes partitus*
Threespot damselfish	*Stegastes planifrons*
Cocoa damslefish	*Stegastes variabilis*
WRASSES	**LABRIDAE**
Spotfin hogfish	*Bodianus pulchellus*
Spanish hogfish	*Bodianus rufus*
Creole wrasse	*Clepticus parrae*
Slippery dick	*Halichoeres bivittatus*
Yellowcheek wrasse	*Halichoeres cyanocephalus*
Yellowhead wrasse	*Halichoeres garnoti*
Clown wrasse	*Halichoeres maculipinna*
Blackear wrasse	*Halichoeres poeyi*
Puddingwife	*Halichoeres radiatus*
Mardi Gras wrasse	*Halichoeres* sp.
Bluehead wrasse	*Thalassoma bifasciatum*
PARROTFISHES	**SCARIDAE**
Bluelip parrotfish	*Cryptotomus roseus*
Rainbow parrotfish	*Scarus guacamaia*
Striped parrotfish	*Scarus iseri*
Princess parrotfish	*Scarus taeniopterus*
Queen parrotfish	*Scarus vetula*
Redband parrotfish	*Sparisoma aurofrenatum*
Redtail parrotfish	*Sparisoma chrysopterum*
Bucktooth parrotfish	*Sparisoma radians*
Redfin parrotfish	*Sparisoma rubripinne*
Stoplight parrotfish	*Sparisoma viride*
THREEFIN SPECIES	**TRIPTERYGIIDAE**
Lofty triplefin	*Enneanectes altivelis*
LABRISOMIDS	**LABRISOMIDAE**
Hairy blenny	*Labrisomus nuchipinnis*
Rosy blenny	*Malacoctenus macropus*
Saddled blenny	*Malacoctenus triangulatus*
Banded blenny	*Paraclinus fasciatus*
GOBIES	**CHAENOPSIDAE**
Roughhead blenny	*Acanthemblemaria aspera*
Sailfin blenny	*Emblemaria pandionis*
COMBTOOTH BLENNIES	**BLENNIIDAE**
Redlip blenny	*Ophioblennius macclurei*
Seaweed blenny	*Parablennius marmoreus*
GOBIES	**GOBIIDAE**
Colon goby	*Coryphopterus dicrus*
Bridled goby	*Coryphopterus glaucofraenum*
Masked/Glass goby	*Coryphopterus hyalinus/personatus*
Jerocho goby	*Elacatinus jerocho*
Neon goby	*Elacatinus oceanops*
Cinta goby	*Elacatinus redimiculus*
Goldspot goby	*Gnatholepis thompsoni*
Spotfin goby	*Oxyurichthys stigmalophius*
SURGEONFISHES	**ACANTHURIDAE**
Ocean surgeon	*Acanthurus bahianus*
Doctorfish	*Acanthurus chirurgus*
Blue tang	*Acanthurus coeruleus*
BARRACUDAS	**SPHYRAENIDAE**
Great barracuda	*Sphyraena barracuda*
Southern sennet	*Sphyraena picudilla*
MACKERELS	**SCOMBRIDAE**
Spanish mackerel	*Scomberomorus maculatus*
LEFTEYE FLOUNDERS	**BOTHIDAE**
Peacock flounder	*Bothus lunatus*
TRIGGERFISHES	**BALISTIDAE**
Ocean triggerfish	*Canthidermis sufflamen*
FILEFISHES	**MONACANTHIDAE**
Orange filefish	*Aluterus schoepfii*
Scrawled filefish	*Aluterus scriptus*
Orangespotted filefish	*Cantherhines pullus*
BOXFISHES	**OSTRACIIDAE**
Spotted trunkfish	*Lactophrys bicaudalis*
Trunkfish	*Lactophrys trigonus*
Smooth trunkfish	*Lactophrys triqueter*
PUFFERS	**TETRAODONTIDAE**
Sharpnose puffer	*Canthigaster rostrata*
Bandtail puffer	*Sphoeroides spengleri*
PORCUPINEFISHES	**DIODONTIDAE**
Porcupinefish	*Diodon hystrix*
	Total species - 155

Table 2. Comparison of abundance for the top-five SIMPER species (*i.e.,* those species contributing most to the assemblage structure differences between regions). P-value from t-test based on $Log_{10}(x + 1)$ transformation.

	Veracruz		Antón Lizardo		
Species	Mean	±SEM	Mean	±SEM	p-value
Chromis multilineata	203.50	51.60	96.50	18.56	**0.0001**
Halichoeres sp.	35.16	8.20	39.54	8.90	0.2819
Abudefduf saxatilis	50.38		13.81	3.36	**0.0001**
		9.06			
Haemulon spp.	41.10	14.55	6.69	3.35	**0.0095**
Coryphopterus hyalinus/personatus	9.82	1.49	18.57	3.74	0.3451
Inermia vittata	32.50	26.63	23.31	10.17	**0.0392**

Benthic Assemblage

Functional group cover — Within the 35 transect samples at the 18 sites, 170 point-intercept transects were completed. An MDS plot of Bray-Curtis similarity indices of functional group cover, including all stony coral species, indicated differences between island groups (VR and ALR) (ANOSIM R-statistic = 0.32) (Figure 2). The functional groups driving differences between VR and ALR were macroalgae (MA), stony coral (SC), and coralline algae (CA) (Figure 3). MA (11.7% ± 2.91) and SC (28.6% ± 2.83) cover were significantly higher in Antón Lizardo than in Veracruz (MA = 3.62% ± 1.66; SC = 14.2% ± 2.81; ANOVA, $p < 0.05$). Conversely, CA coverage was significantly higher in Veracruz (VR = 39.84 ± 6.25 vs. ALR = 21.79% ± 5.41; ANOVA, $p < 0.05$). No significant differences were found between island groups for turf algae (TA) and bare substrate (BS) cover.

The MDS plot of Bray-Curtis similarity indices also indicated differences between Exposure categories (N or S) within island groups (Figure 2). A stronger difference was apparent between Northern and Southern exposure sites at VR (ANOSIM R-statistic = 0.65) than Northern and Southern exposure sites at ALR (ANOSIM R-statistic = 0.38). For both island groups, BS was significantly lower on Northern exposed reefs than Southern exposed reefs (ALR-N = 8.90% ± 1.47; ALR-S = 19.83% ± 4.10 and VR-N = 9.27% ± 2.24; VR-S = 23.35% ± 3.28; ANOVA, $p < 0.05$) (Figure 3). Conversely, CA was significantly greater on Northern exposed sites than Southern exposed sites (VR-N = 59.53% ± 5.14; VR-S = 15.23% ± 3.93 and ALR-N = 37.19% ± 8.41; ALR-S = 8.11% ± 2.45; ANOVA, $p<0.05$). SC coverage was significantly lower at VR-N than on VR-S sites (VR-N = 8.57% ± 2.47; VR-S = 21.27% ± 4.52, ANOVA, $p<0.05$) while ALR-S (28.00% ± 3.33) and ALR-N (29.23% ± 4.95) sites did not differ. MA was significantly higher at ALR-S than ALR-N sites (ALR-S = 18.94% ± 4.14; ALR-N = 3.65% ± 1.24, ANOVA, $p<0.05$) while VR-N (0.55% ± 0.19) and VR-S (7.46% ± 3.36) sites did not differ (Figure 3).

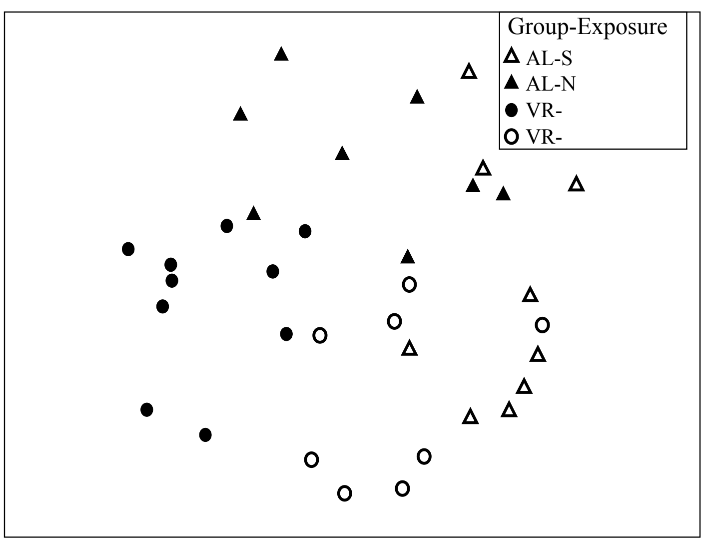

Figure 2. MDS plot of Bray-Curtis similarity indices of coral assemblages. Triangles and circles represent Antón Lizardo and Veracruz, respectively. Shaded and unshaded symbols represent northern and southern exposure of site, respectively.

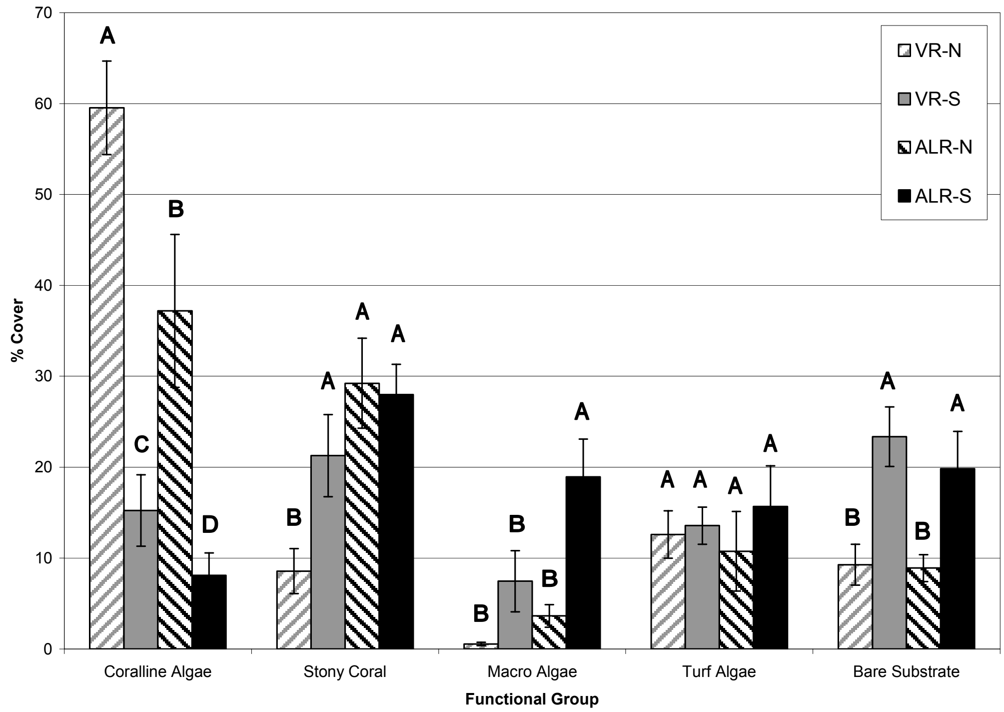

Figure 3. Comparison of mean functional group percent cover by Island Group and Exposure. Grey bars (hatched and solid) represent Veracruz Reefs (VR) and the black bars (hatched and solid) are Antón Lizardo Reefs (ALR). Hatched bars represent Northern exposure (N) and solid bars are Southern exposure (S). The letters indicate significant differences ($p<0.05$, NK) within each functional group.

With island groups pooled, CA was significantly higher on Northern exposed sites (Northern = 49.60% ± 5.28; Southern = 11.46% ± 2.36; ANOVA, $p < 0.05$). Conversely, MA and BS coverage were significantly higher (ANOVA, $p < 0.05$) on Southern exposed sites (MA = 13.54% ± 2.98, BS = 21.49% ± 2.62) than Northern exposed sites (MA = 1.93% ± 0.66, BS = 9.10% ± 1.37).

Stony Corals — A total of 27 stony coral species was identified within the 18 sites (Table 2). Stony coral cover ranged from 3% to 54% (21.2% ± 2.32). Stony coral cover was significantly higher in ALR than VR (ALR = 28.6% ± 2.83; VR = 14.2% ± 2.81; $p < 0.05$, ANOVA). There was little difference in percent cover between the Northern (29.2% ± 4.95) and Southern (28.0% ± 3.33) exposed sites in ALR. The Southern exposed sites in VR (21.3% ± 4.52) had significantly lower percent cover (8.6% ± 2.47; $p < 0.05$, ANOVA) than the Northern exposed sites.

Stony coral species richness ranged from 8 to 15 per site (11.11 ± 0.57). Using the transect colony condition data, *Colpophyllia natans* was the most abundant species (n = 472 colonies) accounting for 20% of the total colonies measured (Table 3). *Montastraea faveolata* (332), *Montastraea cavernosa* (307), *Siderastrea siderea* (159), and *Porites astreoides* (126) were the next most abundant species. Only two species, *Dichocoenia stokesii* and *Stylaster* spp. were seen within the sites but not in any of the transects. No significant differences were found in species richness between island groups or exposure.

The largest colonies identified in both island groups were the *Montastrea annularis* species complex colonies: *M. faveolata* (1.36 m^2 ± 0.14), *M. annularis* (1.30 m^2 ± 0.27), and *M. franksi* (0.94 m^2 ± 0.19). *Montastrea cavernosa* (0.52 m^2 ± 0.05) and *Siderastrea siderea* (0.45 m^2 ± 0.05) were also large, abundant species.

VR had significantly smaller colonies than ALR (VR = 0.37 m^2 ± 0.02; ALR = 0.76 m^2 ± 0.06; ANOVA, $p < 0.01$). Colony size between the Northern and Southern exposure Antón Lizardo sites was not significantly different. The Northern exposed Veracruz sites (0.27m^2 ± 0.02) had smaller colonies than the Southern exposed Veracruz sites (0.44 m^2 ± 0.04) (ANOVA $p = 0.077$).

Stony Coral Disease — Within the 170 transects sampled at the 18 sites, 1812 stony coral colonies were assessed. Of these colonies, 75 (4.14%) were identified with the presence of a disease. Although not significant, ALR sites had a higher mean percentage of disease colonies (4.94% colonies ± 1.13) than VR sites (2.81% colonies ± 0.63). Of the 18 sites, 17 had colonies identified with some type of disease.

Dark spots was the most prevalent, affecting 2.60% of all colonies assessed at 14 sites. Site 6, located in ALR, had the highest incidence of disease (12.74%), but it was solely due to the presence of dark spots disease on *Siderastrea siderea*. This site also had the highest abundance of *S. siderea*. Of the 159 total *S. siderea* colonies assessed, 29.81% were noted with the presence of dark spots disease.

White plague, white band, and yellow band diseases were also observed but at much lower frequency than dark spots disease. White plague was observed in 11 sites affecting five species (*M. faveolata*, *C. natans, D. clivosa*, *M. cavernosa*, and *M. annularis*). White band disease was observed on *Acropora cervicornis* colonies in Site 7. Yellow band disease was observed on *M. faveolata* at two sites (8 and 16).

DISCUSSION

Fishes

The 155 fish species recorded in this study represents the largest species list recorded to date. The addition of species from unpublished surveys increases the number reported from the reefs within the Park to a total of approximately 194. Studies to date used non-destructive, visual counts. Interestingly, a nine-year study at Isla de Lobos off Veracruz, which used a variety of collecting methods including piscicides, recorded only 130 species (Castro-Aguirre and Marquez-Espinoza 1981). Nonetheless, we suspect the use of a piscicide (*e.g.,* rotenone) would likely increase the list of fishes within the Park by 20 to 40% (Ackerman and Bellwood 2000, Willis 2001, Collette *et al.* 2003).

The reason(s) for the higher planktivore abundance at VR is unclear. Apparently, this is not driven by the presence/absence of hydrologic fronts, as there was no apparent difference amongst the VR sites/reefs for the predominant planktivores. Possibly, the influx of nutrients from the Jamapa River or terrestrial run-off from the city of Veracruz and its port are affecting zooplankton abundance. Interestingly, despite the high abundance of diurnal planktivores, few nocturnal planktivores were recorded. For example, only two juvenile apogonids (< 1 cm) were noted. None were recorded during fish surveys, including rover-diver surveys. Although there was no significant difference between VR and ALR in fish species richness, there was a difference between Northern and Southern exposure sites, possibly correlating with coral coverage and colony size (Clua *et al.* 2006).

Taylor and Atkins (2007) described two new gobies from the Veracruz Reef System: *Elacatinus jerocho* and *Elacatinus redimiculus*. While both species were reported to have distributional ranges throughout the Veracruz group and northward to Isla De Lobos, only *E. jerocho* was reported from reefs offshore of ALR (Taylor and Atkins 2007). However, our fish survey shows that demersally associated *E. redimiculus* is found at ALR as well. Furthermore, no significant difference ($p = 0.4258$; ANOVA) was found when comparing its abundance between VR (mean ± SEM: 0.3274 ± 0.1447) and ALR (0.1296 ± 0.0528) island groups, suggesting an even distribution for this species throughout the Veracruz Reef System. In contrast, *E. jerocho* exhibited significantly higher abundance on VR sites (0.9646 ± 0.5543) than those on ALR sites (0.0278 ± 0.0278), which was consistent with the findings for other planktivores ($p = 0.0041$; ANOVA).

Benthic Assemblage

Energy regimes appear to be a major factor shaping the benthic communities in the Veracruz Coral Reef System National Park. In this study, the VR and ALR Northern exposed sites were dominated by coralline algae while macroalgal coverage was significantly higher on the Southern exposed sites. Other researchers have also found that coralline algae coverage increases in higher energy environments (Adey 1998). The Northern exposed sites also had smaller stony corals, with mean stony coral size at the Northern exposure VR sites significantly smaller than at the Southern exposure VR sites. These results are consistent with previous studies of the area (Tunnel 1988, Tunnel 1992, Lara *et al.* 1992) which report that destructive winter storms from the north called "nortes" are common. Effects from local runoff of two major rivers are also thought to impact this system (Tunnel 1988, Tunnel 1992, Lara *et al.* 1992, Jordán-Dahlgren and Rodríguez-Martínez 2003). This potential run-off effect was not specifically addressed in this study.

Benthic community differences were also identified between island groups (VR and ALR). We found stony coral cover in ALR to be significantly higher than in VR. More published information is available for the VR than for ALR. Previously reported stony coral cover for VR has ranged from 40 - 50% in the mid-1960s (Kuhlmann 1975) to 15 - 21% in 1999 (Horta-Puga 2003). This study measured lower stony coral cover at VR sites (14.2%) than Horta-Puga (2003) (17%) reported even though both studies used very similar methodology. Given that Horta-Puga only surveyed windward (Northern exposed) reefs where others have shown to have reduced cover (Lara *et al.* 1992), our stony coral cover estimates perhaps should have been higher because we surveyed both windward (Northern exposed) and leeward reefs (Southern exposed) sites. This result suggests that stony coral cover is still in decline on Veracruz reefs. Several authors have suggested that the decline in *Acropora palmata* and *A. cervicornis* may be driving the loss of stony coral cover (Tunnel 1988, Tunnel 1992, Lara *et al.* 1992, Horta-Puga 2003). Although the loss of acroporid corals may be contributing to reduced cover, these corals may not be the dominate, driving force since Horta-Puga (2003) in his 1999 survey found < 1.5% acroporid cover.

We identified 27 stony coral species, which parallels findings from other studies in the area. Tunnell (1988) listed 28 species of stony corals from the southwestern Gulf reefs, and Lara *et al.* (1992) listed 27 specifically in VR and ALR. Interestingly, Horta-Puga (2003) only found 14 species using a similar sampling technique. However, he only sampled windward, fore reef habitats on three Veracruz reefs (Galleguilla, Isla Verde, and Isle Sacrificios).

C. natans and the *M. annularis* species complex (*M. annularis*, *M. faveolata*, and *M. franksi*) were the most abundant stony coral species assessed along our transects. This was consistent with Lara *et al.* (1992) who found these species to be dominant in fore reef and leeward slope habitats. In addition to being very abundant, *M. annularis*, *M. faveolata*, and *M. franksi* were generally the largest colonies measured at the ALR and VR sites.

In contrast to this study, little evidence of stony coral disease has been previously reported for these reefs (Horta-Puga 2003, Jordán-Dahlgren and Rodríguez-Martínez 2003). This study is the first to quantitatively report disease incidence for these reefs. We identified colonies with dark spots, white plague, white band, and yellow band diseases. Horta-Puga (2003) noted some black band disease, dark spots, and tumors in VR but no quantification was made because none of the surveyed corals were diseased. We found dark spots on 29.8% of the *S. siderea* colonies assessed. Our study suggests that dark spots incidence on *S. siderea* colonies may be increasing since the Horta-Puga (2003) study in 1999 reported an average relative abundance of 17% (some sites as high as 58.5%) of *Siderastrea* spp. without any dark spots.

Previous assessments (Tunnel 1988, Tunnel 1992, Jordán-Dahlgren and Rodríguez-Martínez 2003, and Horta-Puga 2003) have reported declines in *Acropora palmata* and *A. cervicornis*. Our study certainly did not show evidence of recovery of these two species. We identified *A. palmata* in 10 sites (VR and ALR), and we identified *A. cervicornis* in 10 sites (VR and ALR) with *A. cervicornis* being most abundant at the ALR Site 7. A number of sites also had notable standing-dead areas of *A. palmata*.

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