CORAL COMMUNITIES OF SAN JUAN DEL SUR, PACIFIC NICARAGUA

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ABSTRACT

There are few environments conducive to coral growth along the Pacific coast of Nicaragua, due mostly to strong upwelling toward the south and the lack of adequate substrates toward the north. We visited 10 localities along the south coast of Nicaragua (San Juan del Sur, Rivas Department) and used a rapid assessment methodology (four 25-m long transects) to quantify the densities and diversity of coral, fishes, motile macroinvertebrates, and algae. A total of 52 fish, 11 echinoderm, 5 mollusk, 2 crustacean, 13 coral, and 39 macroalgae species were identified along the transects. The mean coral cover was 9.05% ± 1.91, with the highest cover toward the north at Guacalito and Punta Gigante (18.50% ± 8.68 and 16.75% ± 5.25, respectively). The corals *Pavona gigantea* Verrill, 1869 and *Pocillopora* spp. were the main reef-builders. The area between Guacalito and Punta Gigante had the highest abundances of fishes and motile macroinvertebrates and was the most diverse site sampled within the San Juan del Sur area. We propose management action to protect the diversity and uniqueness of this region.

Few shallow habitats for coral reef development occur in the eastern tropical Pacific (ETP). Coral reefs are known to occur within this region at specific sites on the Gulf of California, Mexican mainland, Costa Rica, Panama, Colombia, Ecuador, and their oceanic islands. Coastal margins with extensive mangrove forests, coastal lagoons, and estuaries fragment other potential coral reefs habitats (Glynn and Ault 2000). In addition, the reef fauna at some ETP localities are still unknown. Of special interest is the area between southern Mexico and Nicaragua, a distance of approximately 1000 km, known as the "Pacific Central American faunal gap" (Springer 1958, Glynn and Ault 2000). ETP coral reefs are thin $CaCO_3$ veneers, compared to their counterparts in the Indo-Pacific and Caribbean (Manzello et al. 2008). They are relatively small (1–2 ha), discontinuous, limited to shallow waters (< 10 m), formed by few species, and geologically ephemeral (Cortés 2003).

The Pacific coast of Nicaragua is characterized by a combination of rocky points, sand and rubble beaches, and nearshore marine communities influenced by seasonal upwelling along the south coast (Cortés 2007). This coast is one of the most oceanographically dynamic along the Central American Pacific; however, it is one of the least studied localities (Brenes et al. 2000). There are few records of coral reefs along this coast of Nicaragua (Durham and Barnard 1952, Glynn and Ault 2000, Spalding et al. 2001), although there are isolated coral colonies and possibly more developed coral features close to the border with Costa Rica (Cortés 2007). Along the Pacific coast, Ryan and Zapata (2003) observed only solitary pocilloporid colonies and octo-corals in San Juan del Sur (SJdS).

One of the reasons for such meager reef development is the oceanography of the area. Papagayo upwelling along the coast is one of the three major coastal upwelling areas within the ETP. During the dry season (December–April), trade winds blow across the Gulf of Mexico and the Caribbean to the Pacific, causing shoaling of the thermocline, high chlorophyll concentrations (maximum of 22 mg m^{-3}, relative to ETP average of 0.3 mg m^{-3}), increased productivity (365 mg C m^{-3} d^{-1}), and low temperatures (Pennington et al. 2006). Glynn et al. (1983) argued that the intense, prolonged upwelling in Papagayo is less conducive to reef development than non-upwelling areas in Costa Rica and Panama (Gulf of Chiriquí), as well the upwelling Gulf of Panama. During this prolonged upwelling season, the mean minimum temperatures drop below 20 °C (18–19 °C) for more than 3 mo (Glynn et al. 1983). Because this is below the thermal limit that has been proposed for coral reef development (Kleypas et al. 1999), coral recruitment and survival are low, leading to poor reef development (Glynn et al. 1983).

Due to the paucity of published data on the coral communities along the southern Pacific coast of Nicaragua, we used a rapid assessment methodology to describe the distribution and composition of the coral reef communities and their associated fauna and flora. Here we present novel information on coral cover at 10 localities off SJdS, Nicaragua, including data on the composition of the ichthyofauna, motile macroinvertebrates, and important macroalgae in the area.

Materials and Methods

SJdS is located in the Rivas Department (11°23′N, 86°02′W and 11°07′N, 85°47′W), along the southern Pacific coast of Nicaragua. Ten localities in this area were sampled in July 2009 (Fig. 1). We quantified the distribution and composition of bottom cover, motile macroinvertebrates, and fishes at each locality by laying out four, 25-m line-transects parallel to the coast, between a depth of 6 and 12 m. We first counted all fishes within 2.5 m of each side of the transect and up to 5 m above. On the same line-transect, we quantified bottom cover every 25 cm by noting the cover under each point as one of the following categories: live coral, turf, macroalgae (fleshy algae), crustose coralline algae, rock, rubble, or sand. We quantified all motile macroinvertebrates (sea stars, sea cucumbers, sea urchins, gastropods, conspicuous bivalves, arrow crabs, and lobsters) present in a band 1 m to each side of the transect (50 m^2) without removing any rock or coral head. At the same time, we collected samples of macroalgae for further identification. Algal samples were preserved in 4% formalin/seawater and air-dried pressed on herbarium sheets for archiving. A complete set of specimens is archived at the herbaria at the Universidad Autónoma de León, Nicaragua, and at the Universidad de Costa Rica.

For each locality, fish and macroinvetebrate diversity indices (Shannon-Wiener, Pielou, and taxonomic distinctiveness; Clarke and Warwick 2001) were estimated using the total numbers of individuals. The composition similarity was analyzed through a Bray-Curtis similarity index. To identify patterns of composition similarities among localities, data were $\log_{10}(x + 1)$-transformed to achieve normality and used to create a cluster tree and a nonmetric multidimensional scaling (nMDS) graph (using the software PRIMER 6.1.4).

ANOVA techniques were applied to determine percent cover differences for each category among localities. Data were square-root-transformed to achieve normality. Data not conforming to parametric statistical requirements were tested using a Kruskal-Wallis analysis of variance. All statistical analyses were performed using the software SigmaStat 3.5.

Using these new data on the coral composition in southern Nicaragua, and data from the literature on the other countries, states (Mexico), and oceanic islands in the ETP (Reyes-Bonilla and Barraza 2003, Reyes-Bonilla et al. 2005, Glynn et al. 2007), we constructed a matrix
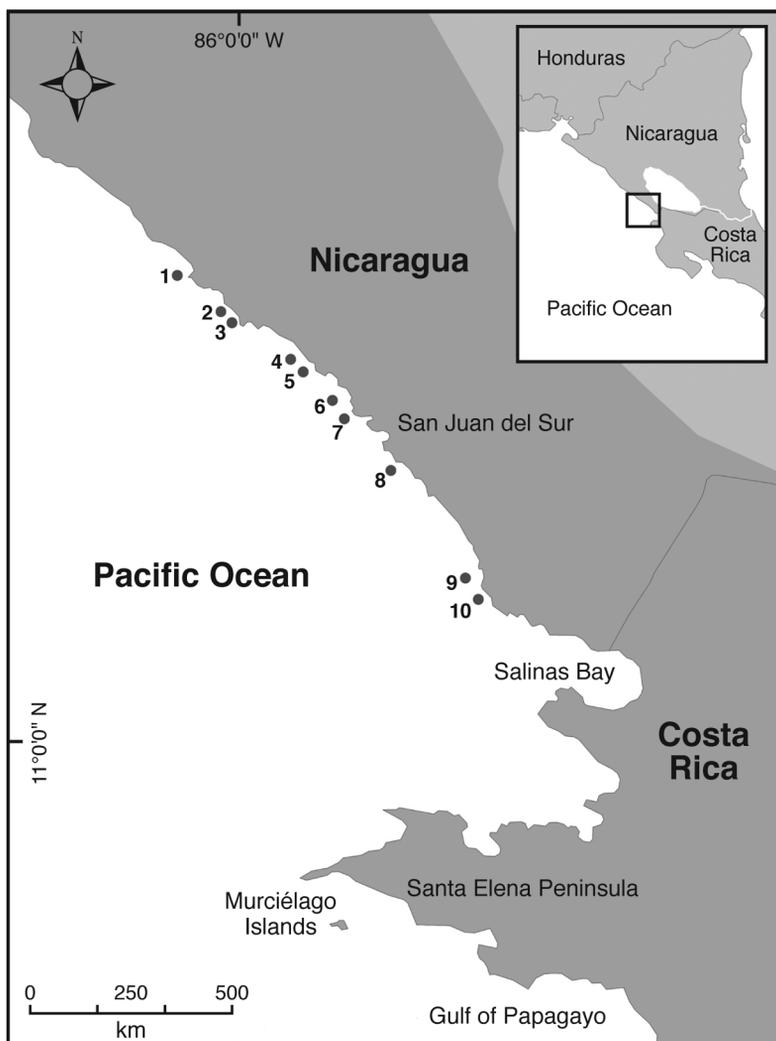
Figure 1. Location of sampling sites along the south Pacific coast of Nicaragua. 1: Punta Gigante; 2: Guacalito; 3: La Anciana; 4: Punta El Clavo; 5: Costa Blanca; 6: Marsella; 7: El Toro; 8: Peña Rota; 9: La Flor; 10: La Cagada.

of presence/absence of each hermatypic scleractinian species. To compare the similarities, we constructed a Bray-Curtis similarity index, which was plotted in a cluster analysis.

Results

During the surveys, we identified a total of 52 fish species belonging to 23 families and 41 genera (Table 1). The richest families were Labridae and Pomacentridae, with eight and six species, respectively. Within the Labridae, the genus *Halichoeres* was the most diverse with five species. Four species were abundant in the study area (accounting for over 100 of 3142 total individuals): *Chromis atrilobata, Caranx caballus, Halichoeres dispilus*, and *Stegastes acapulcoensis*. Each of these species

Table 1. Mean densities (ind m^{-2} ± SE), diversity index (H'), evenness (J), and taxonomic distinctiveness (Δ+) of reef fishes along the sampled sites on the south Pacific coast of Nicaragua. 1: Punta Gigante; 2: Guacalito; 3: La Anciana; 4: Punta El Clavo; 5: Costa Blanca; 6: Marsella; 7: El Toro; 8: Peña Rota; 9: La Flor; 10: La Cagada.

Family/Species	1	2	3	4	5	6	7	8	9	10
Acanthuridae										
Acanthurus xanthopterus Valenciennes, 1835	0.004 ± 0.002	–		–	–	–	–	–	–	–
Balistidae										
Balistes polylepis Steindachner, 1876	–	–	0.002 ± 0.002	–	–	–	–	–	–	–
Sufflamen verres (Gilbert and Starks, 1904)	0.006 ± 0.002	0.002 ± 0.002	–	–	–	–	–	–	0.002 ± 0.002	0.002 ± 0.002
Blenniidae										
Ophioblennius steindachneri Jordan and Evermann, 1898	–	–	–	–	–	0.004 ± 0.002	–	–	–	–
Plagiotremus azaleus (Jordan and Bollman, 1890)	0.006 ± 0.006	0.002 ± 0.002	0.016 ± 0.014	–	–	–	–	0.002 ± 0.002	0.012 ± 0.007	0.014 ± 0.014
Carangidae										
Caranx caballus Günther, 1868	0.138 ± 0.058	–	–	–	–	–	–	0.580 ± 0.483	0.018 ± 0.016	0.350 ± 0.218
Chaetodontidae										
Chaetodon humeralis Günther, 1860	0.016 ± 0.007	0.018 ± 0.013	0.008 ± 0.008	0.004 ± 0.002	0.002 ± 0.002	–	0.004 ± 0.004	0.018 ± 0.018	0.016 ± 0.008	0.014 ± 0.007
Johnrandallia nigrirostris (Gill, 1862)	0.014 ± 0.007	0.012 ± 0.010	0.006 ± 0.004	–	0.004 ± 0.004	–	–	0.006 ± 0.004	0.002 ± 0.002	0.002 ± 0.002
Cirrhitidae										
Cirrhitichthys oxycephalus (Bleeker, 1855)	–	–	0.002 ± 0.002	–	0.002 ± 0.002	–	–	–	–	–
Cirrhitus rivulatus Valenciennes, 1846	–	–	–	0.002 ± 0.002	0.002 ± 0.002	0.008 ± 0.004	–	0.002 ± 0.002	–	–
Diodontidae										
Diodon holocanthus Linnaeus, 1758	0.002 ± 0.002	0.002 ± 0.02	0.004 ± 0.004	–	–	–	0.002 ± 0.002	0.002 ± 0.002	0.004 ± 0.002	–
Diodon hystrix Linnaeus, 1758	–	–	–	–	–	–	–	0.002 ± 0.002	–	–
Haemulidae										
Anisotremus dovii (Günther, 1864)	–	–	0.002 ± 0.002	–	–	–	–	–	–	–

Table 1. Continued.

Family/Species	1	2	3	4	5	6	7	8	9	10
Haemulon maculicauda (Gill, 1862)	–	0.004 ± 0.004	–	–	–	–	–	0.002 ± 0.002	–	0.016 ± 0.016
Haemulon sexfasciatum Gill, 1862	–	0.002 ± 0.002	–	–	–	–	–	–	–	–
Haemulon steindachneri (Jordan and Gilbert, 1882)	–	–	–	–	–	–	–	–	0.014 ± 0.012	0.014 ± 0.009
Holocentridae										
Myripristis leiognathus Valenciennes, 1846	–	0.002 ± 0.002	0.004 ± 0.004	–	–	–	–	–	–	0.006 ± 0.004
Sargocentron suborbitalis (Gill, 1863)	–	0.004 ± 0.004	0.002 ± 0.002	–	0.002 ± 0.002	0.006 ± 0.004	–	–	–	–
Labridae										
Bodianus diplotaenia (Gill, 1862)	0.016 ± 0.007	0.016 ± 0.014	0.014 ± 0.006	–	0.010 ± 0.005	0.010 ± 0.005	–	–	0.006 ± 0.004	0.004 ± 0.004
Halichoeres chierchiae Di Caporiacco, 1948	–	0.004 ± 0.002	0.008 ± 0.004	–	0.006 ± 0.004	–	0.008 ± 0.008	–	–	–
Halichoeres dispilus (Günther, 1864)	0.120 ± 0.057	0.120 ± 0.060	0.050 ± 0.018	0.054 ± 0.023	0.058 ± 0.037	0.016 ± 0.010	0.028 ± 0.016	0.062 ± 0.033	0.088 ± 0.078	0.056 ± 0.020
Halichoeres melanosis (Gilbert, 1890)	–	–	–	–	–	–	–	0.006 ± 0.006	–	–
Halichoeres nicholsi (Jordan and Gilbert, 1882)	0.010 ± 0.005	0.016 ± 0.014	0.010 ± 0.005	–	0.006 ± 0.004	0.002 ± 0.002	–	–	–	–
Halichoeres notospilus (Günther, 1864)	–	–	0.008 ± 0.006	0.004 ± 0.002	0.008 ± 0.005	–	0.012 ± 0.012	–	0.002 ± 0.002	–
Thalassoma grammaticum Gilbert, 1890	–	–	–	–		–	–	–	0.002 ± 0.002	–
Thalassoma lucasanum (Gill, 1862)	0.006 ± 0.004	–	0.016 ± 0.007	–	–	0.066 ± 0.030	0.020 ± 0.020	0.002 ± 0.002	–	–
Lutjanidae										
Hoplopagrus guentherii Gill, 1862	–	–	–	–	–	–	–	–	0.002 ± 0.002	–
Lutjanus argentiventris (Peters, 1869)	0.032 ± 0.025	0.010 ± 0.005	0.002 ± 0.002	–	0.002 ± 0.002	–	0.004 ± 0.004	0.022 ± 0.016	0.026 ± 0.016	0.004 ± 0.004
Lutjanus guttatus (Steindachner, 1869)	–	–	–	–	–	–	–	–	0.002 ± 0.002	–

Table 1. Continued.

Family/Species	1	2	3	4	5	6	7	8	9	10
Mullidae										
Mulloidichthys dentatus (Gill, 1862)	–	0.002 ± 0.002	–	–	–	–	–	–	–	–
Muraenidae										
Muraena lentiginosa Jenyns, 1842	0.002 ± 0.002	–	–	–	–	–	–	–	–	–
Pomacanthidae										
Holacanthus passer Valenciennes, 1846	0.004 ± 0.004	–	–	–	0.002 ± 0.002	–	–	–	–	–
Pomacanthus zonipectus (Gill, 1862)	–	–	–	0.004 ± 0.002	–	–	–	–	–	–
Pomacentridae										
Abudefduf concolor (Gill, 1862)	–	–	–	–	0.006 ± 0.006	–	0.002 ± 0.002	–	–	–
Abudefduf troschelii (Gill, 1862)	–	–	0.016 ± 0.014	0.004 ± 0.004	–	0.006 ± 0.006	0.002 ± 0.002	–	–	0.088 ± 0.032
Chromis atrilobata Gill, 1862	0.820 ± 0.543	0.220 ± 0.196	0.240 ± 0.175	–	–	0.740 ± 0.364	0.312 ± 0.211	0.060 ± 0.060	0.096 ± 0.068	–
Microspathodon dorsalis (Gill, 1862)	0.008 ± 0.004	–	0.002 ± 0.002	–	0.022 ± 0.013	0.032 ± 0.014	–	–	–	–
Stegastes acapulcoensis (Fowler, 1944)	0.032 ± 0.018	0.034 ± 0.017	0.148 ± 0.049	0.036 ± 0.018	0.176 ± 0.058	0.200 ± 0.057	0.162 ± 0.061	0.002 ± 0.002	0.008 ± 0.008	0.016 ± 0.004
Stegastes flavilatus (Gill, 1862)	0.016 ± 0.004	0.006 ± 0.004	0.008 ± 0.006	0.016 ± 0.010	0.014 ± 0.009	–	–	0.030 ± 0.013	0.004 ± 0.004	–
Scaridae										
Nicholsina denticulata (Evermann and Radcliffe, 1917)	–	0.004 ± 0.004	–	–	–	–	–	–	–	–
Scarus perrico Jordan and Gilbert, 1882	–	0.004 ± 0.004	–	–	–	–	–	0.008 ± 0.008	–	–
Sciaenidea										
Pareques sp.	–	–	0.004 ± 0.004	–	0.002 ± 0.002	–	–	–	–	–
Serranidae										
Alphestes immaculatus Breder, 1936	0.002 ± 0.002	–	–	–	0.004 ± 0.004	–	–	–	–	–

Table 1. Continued.

Family/Species	1	2	3	4	5	6	7	8	9	10
Cephalopholis panamensis (Steindachner, 1877)	0.002 ± 0.002	0.016 ± 0.005	0.002 ± 0.002	–	0.002 ± 0.002	0.014 ± 0.006	–	0.02 ± 0.002	–	0.008 ± 0.004
Epinephelus labriformis (Jenyns, 1840)	0.012 ± 0.006	0.004 ± 0.004	0.028 ± 0.017	0.004 ± 0.004	0.002 ± 0.002	0.012 ± 0.005	–	0.004 ± 0.004	–	0.010 ± 0.004
Serranus psittacinus Valenciennes, 1846	0.002 ± 0.002	–	–	–	–	–	–	–	–	0.006 ± 0.006
Sparidae										
Calamus brachysomus (Lockington, 1880)	–	–	–	–	–	–	–	–	0.002 ± 0.002	0.012 ± 0.008
Synodontidae										
Synodus lacertinus Gilbert, 1890	0.002 ± 0.002	–	–	–	–	–	–	–	–	–
Tetraodontidae										
Arothron meleagris (Lacépède, 1798)	–	–	–	–	0.002 ± 0.002	–	0.006 ± 0.006	–	–	–
Canthigaster punctatissima (Günther, 1870)	0.004 ± 0.002	0.004 ± 0.004	0.006 ± 0.006	–	–	–	–	–	–	–
Sphoeroides lobatus (Steindachner, 1870)	0.002 ± 0.002	–	–	–	–	–	–	–	–	–
Urotrygonidae										
Urobatis concentricus Osburn and Nichols, 1916	–	–	–	–	0.002 ± 0.002	–	–	–	–	0.002 ± 0.002
Species total	25	23	25	9	22	13	12	18	18	18
Diversity (H')	1.467	1.945	2.057	1.587	1.803	1.179	1.275	1.196	2.037	1.673
Eveness (J')	0.456	0.620	0.639	0.722	0.583	0.460	0.513	0.414	0.705	0.579
Taxonomic distinctiveness ($\Delta+$)	39.64	36.79	36.73	34.6	39.83	36.01	40.91	39.33	39.57	45.51

individually represented > 10% of the total abundance, and together represented 80.2% of the total population. The remaining species were relatively rare (each < 2.5% of the total). *Stegastus acapulcoensis* and *H. dispilus* were the only species found at all of the 10 localities sampled. The highest densities of *C. atrilobata* were observed in Punta Gigante and Marsella, with 0.820 ind m^{-2} and 0.740 ind m^{-2}, respectively (Table 1). Differences among localities were statistically nonsignificant (Kruskal-Wallis: H$_{9,40}$ = 15.79, P = 0.07).

The number of fish species ranged from nine to 25 species and varied significantly among localities (Kruskal-Wallis: H$_{9,40}$ = 20.16, P < 0.05). The most depauperate site was Punta El Clavo, while Punta Gigante and La Anciana were the most speciose with 25 each (Table 1). La Anciana and La Flor had the highest fish diversity (H': 2.057 and 2.037, respectively), and Marsella the lowest (1.179, Table 1). Punta El Clavo and La Flor had the highest evenness values (0.722 and 0.705, respectively), and Peña Rota the lowest values (0.414). In the case of taxonomic distinctiveness (Δ+), the richest locations were La Cagada at 45.51, El Toro at 40.91, and Punta Gigante at 39.64, while the poorest was Marsella (36.01, Table 1).

Along the transects, we identified 18 species of motile macroinvertebrates, including 5 mollusks, 2 crustaceans, and 11 echinoderms (1 asteroid, 6 echinoids, and 4 holothuroids; Table 2). No macroinvertebrates were present at all localities. The sea urchin *Diadema mexicanum* was present at nine localities (all except La Cagada). This sea urchin was the most abundant, with the highest density at Punta Gigante (1.10 ± 0.20 ind m^{-2}; Kruskal-Wallis: H$_{9,40}$ = 23.71, P < 0.01). In the majority of the localities, we recorded low densities of mollusks and crustaceans (0.01 ind m^{-2}), with the exception of the gastropod *Vasum caestus* at La Flor (0.05 ± 0.05 ind m^{-2}) and the crab *Stenorhynchus debilis* (0.03 ± 0.02 ind m^{-2}) at Peña Rota. Note that for the lobster *Panulirus gracilis*, as well as for the sea cucumbers, there are no fishing regulations on the Pacific coast of Nicaragua, thus small, immature individuals are regularly harvested.

The locality with the richest motile macroinvertebrates was La Anciana, where we observed 12 species, followed by Punta Gigante and Peña Rota with 10 species each, while the least speciose localities were Costa Blanca and El Toro, with three taxa at both localities (Table 2). La Cagada and La Flor had the highest values of diversity and evenness (1.706 and 0.882, respectively), and Marsella had the lowest values of diversity (0.279) and evenness (0.144, Table 2).

The cluster and nMDS analyses revealed three main groups, according to their similarity (45%) in composition of fishes and motile macroinvertebrates (Fig. 2A,B). The first group (58%) was formed by Punta Gigante, Guacalito, La Anciana, and Peña Rota. The first three localities are the northern-most sites of the study area (Fig. 1). The two southern-most sites, La Flor and La Cagada, formed the second group, while the intermediate sites of Punta El Clavo, Costa Blanca, Marsella, and El Toro comprised the third group (Figs. 1–2).

Within the 10 sampling locations, 13 scleractinian coral species were identified (nine zooxanthellate: *Pavona clavus* (Dana, 1846), *Pavona gigantea* Verrill, 1869, *Pavona varians* Verrill, 1864, *Gardineroseris planulata* (Dana, 1846), *Porites panamensis* Verrill, 1866, *Psammocora stellata* Verrill, 1866, *Psammocora obtusangula* (Lamarck, 1816), *Pocillopora elegans* Dana, 1846, and *Pocillopora damicornis* (Linnaeus, 1758); and four azooxanthellates: *Oulangia bradleyi* (Verrill, 1866), *Astrangia* spp., *Tubastrea coccinea* Lesson, 1831, and *Phyllangia* cf. *dispersa* Verrill, 1864.

Table 2. Mean densities (ind m^{-2} ± SE), diversity index (H'), and evenness (J') of motile macroinvertebrates along the sampled sites along the south Pacific coast of Nicaragua. 1: Punta Gigante; 2: Guacalito; 3: La Anciana; 4: Punta El Clavo; 5: Costa Blanca; 6: Marsella; 7: El Toro; 8: Peña Rota; 9: La Flor; 10: La Cagada.

| Taxa/Species	1	2	3	4	5	6	7	8	9	10
Mollusca										
Pinctada mazatlanica (Hanley, 1856)	0.03 ± 0.01	0.04 ± 0.01	–	0.01 ± 0.01	–	0.01 ± 0.01	0.01 ± 0.01	0.02 ± 0.02	–	0.01 ± 0.01
Pleuroploca princeps (Sowerby, 1825)	–	–	0.01 ± 0.01	–	–	–	–	–	–	–
Vasum caestus (Broderip, 1833)	0.01 ± 0.01	0.01 ± 0.01	–	–	–	–	–	–	0.05 ± 0.05	0.02 ± 0.01
Hexaplex princeps (Broderip, 1833)	–	–	–	–	–	0.01 ± 0.01	–	0.03 ± 0.03	–	0.01 ± 0.01
Strombus galeatus (Swainson, 1823)	–	–	–	0.01 ± 0.01	–	–	–	–	–	–
Crustacea										
Panulirus gracilis Streets, 1871	–	–	0.01 ± 0.01	–	–	–	–	–	0.01 ± 0.01	–
Stenorhynchus debilis (Smith, 1871)	0.01 ± 0.01	–	0.01 ± 0.01	–	–	–	–	0.03 ± 0.02	–	0.01 ± 0.01
Echinodermata										
Phataria unifacialis (Gray, 1840)	0.10 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	–	–	–	–	0.04 ± 0.02	–	–
Eucidaris thouarsii (Valenciennes, 1846)	0.03 ± 0.01	0.01 ± 0.01	0.02 ± 0.02	0.01 ± 0.01	–	0.04 ± 0.03	–	0.09 ± 0.06	0.08 ± 0.00	0.05 ± 0.02
Astropyga pulvinata (Lamarck, 1816)	–	0.01 ± 0.01	0.39 ± 0.38	0.03 ± 0.02	–	–	–	0.02 ± 0.01	0.01 ± 0.01	–
Diadema mexicanum A. Agassiz, 1863	1.10 ± 0.20	0.16 ± 0.04	0.77 ± 0.23	0.19 ± 0.08	0.04 ± 0.02	0.08 ± 0.03	0.51 ± 0.37	0.25 ± 0.19	0.04 ± 0.04	–
Echinometra vanbrunti A. Agassiz, 1863	0.01 ± 0.01	–	0.27 ± 0.27	–	0.15 ± 0.02	4.09 ± 1.11	0.07 ± 0.07	0.04 ± 0.02	–	–
Tripneustes depressus A. Agassiz, 1863	0.01 ± 0.01	–	0.01 ± 0.01	–	–	–	–	–	–	–
Toxopneustes roseus (A. Agassiz, 1863)	0.02 ± 0.02	–	0.01 ± 0.01	–	0.01 ± 0.01	–	–	0.01 ± 0.01	–	–
Cucumaria flamma Solís and Laguarda, 1999	0.02 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	–	–	0.01 ± 0.01	–	0.01 ± 0.01	0.04 ± 0.04	0.01 ± 0.01
Isostichopus fuscus (Ludwig, 1875)	–	0.01 ± 0.01	0.01 ± 0.01	–	–	–	–	–	–	–
Holothuria sp.	–	–	–	–	0.01 ± 0.01	–	–	–	–	0.01 ± 0.01
Pseudocnus sp.	–	–	–	–	–	0.09 ± 0.05	–	–	–	0.01 ± 0.01
Species total	10	8	12	5	3	7	3	10	6	8
Diversity (H')	0.710	1.243	1.265	0.691	0.630	0.279	0.399	1.674	1.580	1.706
Eveness (J')	0.308	0.598	0.509	0.429	0.574	0.144	0.364	0.727	0.882	0.820
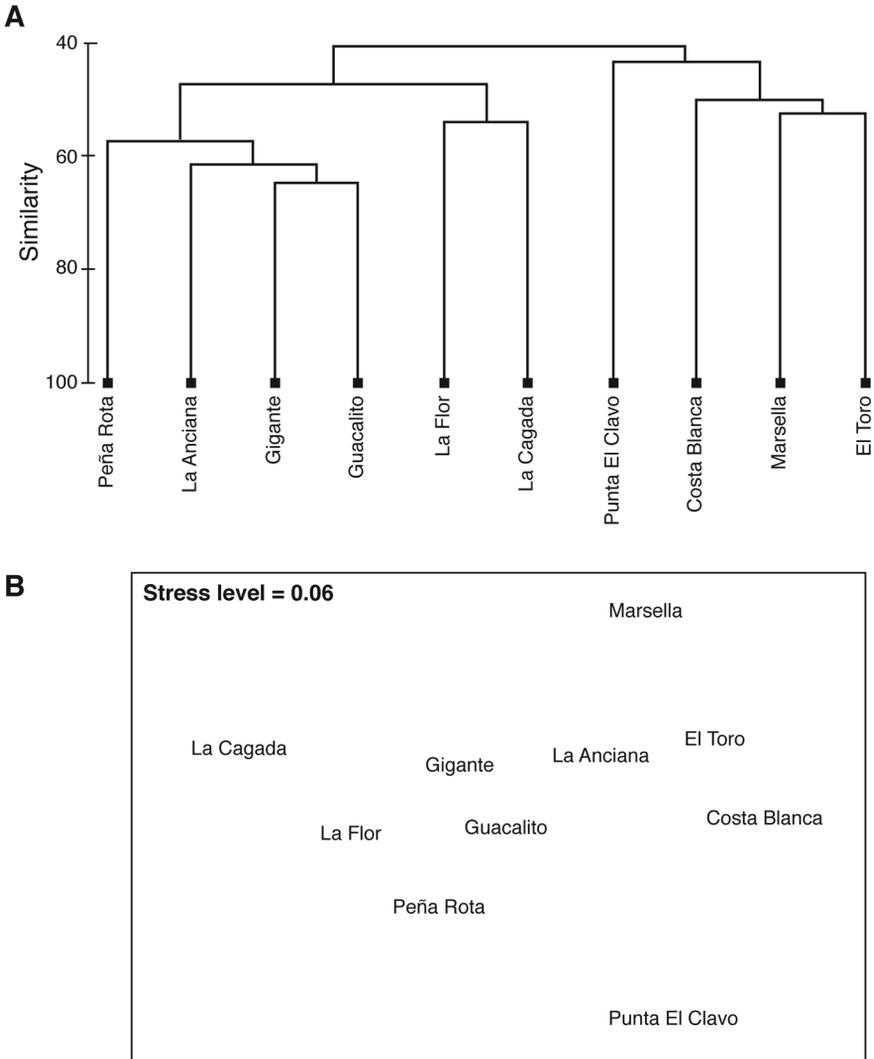
Figure 2. (A) dendrogram and (B) nMDS; based on a combined Bray-Curtis similarity index matrix of fishes and motile macroinvertebrate abundances [$\log_{10}(x + 1)$-transformed] of sampled sites along the south Pacific coast of Nicaragua.

Along the transects, *P. gigantea* (31.7%, Alvarado et al. 2010) was the predominant coral, followed by *Pocillopora* spp. (23.9%), *P. panamensis* (21.1%), and *P. clavus* (14.9%). The remaining species accounted for only 8.4%.

With regards to corals, Punta Gigante and Guacalito were the richest localities, with five species of coral present at both sites, followed by La Anciana and El Toro with four species, and Costa Blanca with three species. The region between Gigante and La Anciana included all nine reef-building corals observed in this survey and was the most important area for coral development. Mean coral cover (9.05% ± 1.91) varied significantly among localities (ANOVA: $F_{9, 28} = 1.33$, P = 0.27), with the high-
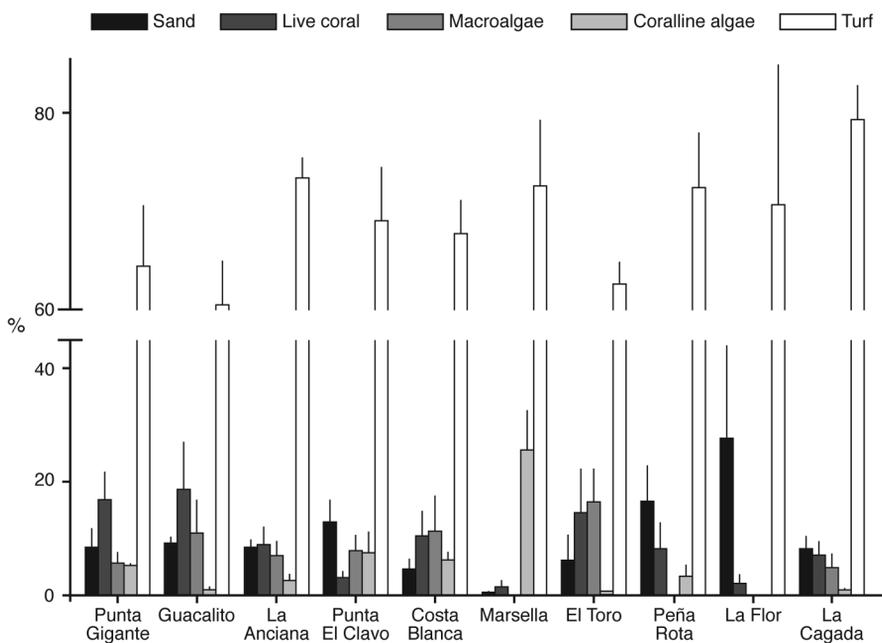
Figure 3. Average percent of substrate cover (± SE) along the sampled sites on the south Pacific coast of Nicaragua.

est coral cover at Guacalito (18.50% ± 8.68, Fig. 3), followed by Punta Gigante with 16.75% ± 5.25.

Mean coralline algae cover was 5.28% ± 2.39, with significantly higher values at Marsella than the other sites (25.50% ± 7.14, ANOVA: $F_{9, 28}$ = 6.96, P < 0.001, Tukey P < 0.05, Fig. 3). At Marsella, we also observed the highest number of *Echinometra vanbrunti* sea urchins, with a total of 818 individuals counted along the transects (4.09 ± 1.11 ind m^{-2}, Table 2).

We recorded a total of 39 species of marine macroalgae from the south coast of Nicaragua: 16 spp. of rhodophytes, 14 chlorophytes, eight phaeophytes, and one cyanophyte (Table 3). Mean turf algae cover was 69.18% ± 1.78 and differed significantly among localities (ANOVA: $F_{9, 28}$ = 1.21, P = 0.33), with the highest cover at La Cagada (79.25% ± 3.59, Fig. 3). Mean macroalga (fleshy algae) cover was 7.06% ± 1.69 and differed significantly among localities (Kruskal-Wallis: $H_{9, 28}$ = 17.43, P < 0.05). The highest macroalga cover was at El Toro (16.5% ± 5.85), where extensive *Sargassum* patches were observed.

The analysis of coral composition by state or country along the ETP revealed four groups (shading squares, Fig. 4). The first group is composed of Sonora, Sinaloa, and Baja California, which are the areas with the fewest number of species (1–3). The second group is composed of the Mexican States of Guerrero, Jalisco, Colima, Michoacán, and the countries of El Salvador and Nicaragua, all with an intermediate (6–12) number of species. The last two groups are composed of the countries with highest coral species richness. The oceanic islands of Revillagigedo, Clipperton, and the State of Nayarit (Marías Island) have 17–19 species, while the last group of Baja California Sur, Oaxaca, Costa Rica, Panama, Colombia, Ecuador, and the oceanic islands of Coco and Galápagos have 17–23 species. This last group also includes the locations with the highest coral cover of the region.

Table 3. List of marine macroalgae sampled from reef sites along San Juan del Sur, Nicaragua.

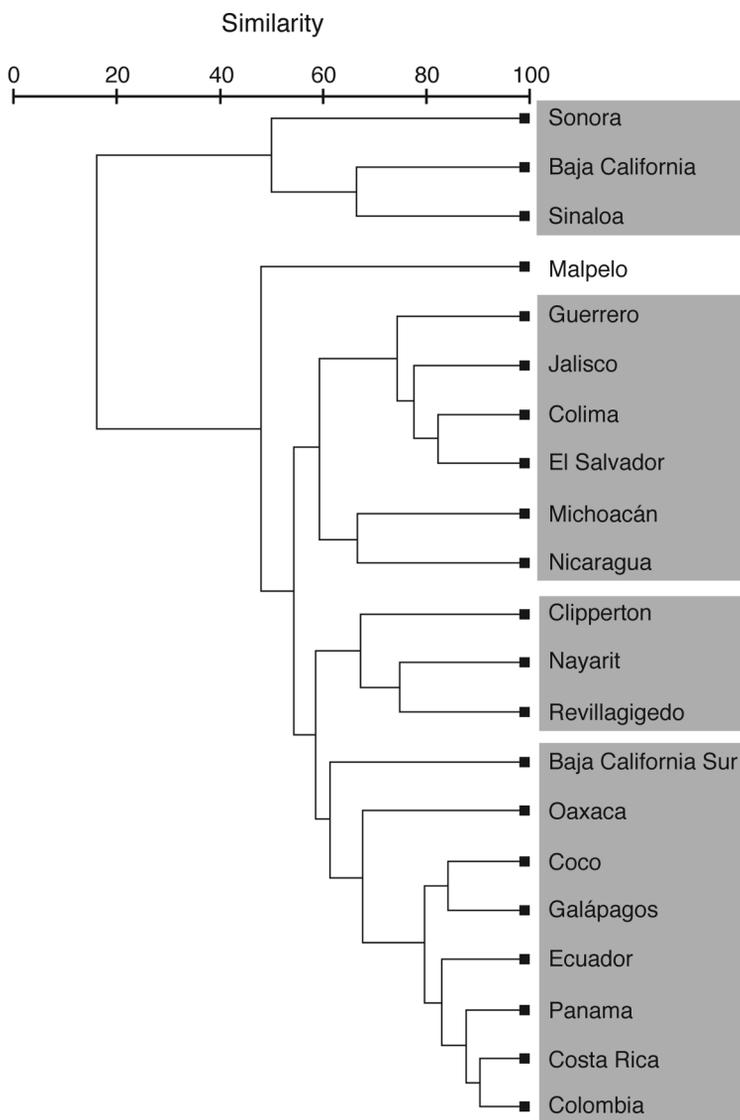| Phylum/Family	Species
Cyanophyta	
Oscillatoriaceae	*Symploca hypnoides* Kützing ex Gomot, 1892
Ochrophyta	
Phaeophyceae	*Padina durvillaei* Bory, 1827
	Padina sp.
Dictyotaceae	*Dictyota stolonifera* Dawson, 1962
	Dictyota sp. 1
	Dictyota sp. 2
	Dictyopteris sp.
	Lobophora variegata (J.V. Lamouroux) Womersley ex E.C. Oliveira, 1977
Sargassaceae	*Sargassum liebmannii* J. Agardh, 1847
Chlorophyta	
Ulvaceae	*Ulva lactuca* Linnaeus, 1753
	Ulva sp. 1 (blade form)
	Ulva sp. 2 (tubular form)
Cladophoraceae	*Chaetomorpha antennina* (Bory) Kützing, 1847
	Cladophora sp.
Bryopsidaceae	*Bryopsis pennata* J.V. Lamouroux, 1809
	Bryopsis sp.
Caulerparceae	*Caulerpa racemosa* var. *peltata* (J.V. Lamouroux) Eubank, 1944
	Caulerpa racemosa (Forsskål) J. Agardh, 1873
Codiaceae	*Codium picturatum* F.F. Pedroche & P.C. Silva, 1996
	Codium isabelae W.R. Taylor, 1945
Halimedaceae	*Halimeda discoidea* Descaine, 1842
Udoteaceae	*Chlorodesmis caespitosa* J. Agardh, 1887
Dasycladaceae	*Parvocaulis parvula* (Solms-Laubach) S. Berger et al., 2003
Rhodophyta	
Corallinaceae	*Amphiroa misakiensis* Yendo, 1902
	Amphiroa sp. 1
	Amphiroa sp. 2
	Jania sp.
	Lithophyllum sp.
Galaxauraceae	*Dichotomaria marginata* (Ellis & Solander) J.V. Lamouroux, 1816
Ceramiaceae	*Ceramium* spp.
Rhodomelaceae	*Polysiphonia* sp.
Gelidiaceae	*Gelidium* sp.
Gelidiellaceae	*Gelidiella* sp.
Cystocloniaceae	*Hypnea pannosa* J. Agardh, 1847
Peyssoneliaceae	*Peyssonnelia* sp.
Champiaceae	*Champia* sp.
Wrangeliaceae	*Wrangelia* sp.
	Haloplegma sp.
Gracilariaceae	*Gracilaria* sp.

Figure 4. Similarity of composition of the hermatypic scleractinian species in the Eastern Tropical Pacific based on a Bray-Curtis matrix of presence/absence (based on Reyes-Bonilla and Barraza 2003, Reyes-Bonilla et al. 2005, Glynn et al. 2007; shading indicates similar groups).

Discussion

Historically, the Pacific coast of Nicaragua has been considered as lacking coral biotopes, with only a few isolated coral colonies of the genus *Pocillopora* existing near Costa Rica (Glynn and Ault 2000, Ryan and Zapata 2003, Cortés 2007). However, our study has documented the presence of coral biotopes along the coast of SJdS. Thus, lack of knowledge was primarily due to the scarcity of research in this area, stemming from the difficulty of conducting research under challenging socio-political

conditions and the lack of specialists in the country. Our research has documented the existence of coral reefs (predominantly composed of *P. gigantea*) populated by 13 coral species, 52 fish species, 11 echinoderm species, and 39 species of algae.

The coral reef fishes of SJdS are less diverse than other, more developed reef areas in the ETP, but are similar to those located in stressful environments (e.g., upwelling areas). As in other upwelling areas of the ETP (Dominici-Arosemena et al. 2005, Espinoza and Salas 2005, Ramírez et al. 2007, Benfield et al. 2008), *C. atrilobata* is the most abundant species at SJdS. In Huatulco, Mexico, fish diversity is highest between June and August, when the upwelling season is over; because during the upwelling season, the area is too cold for coral reef fishes (Ramirez et al. 2007). Our study took place in July, when the Papagayo upwelling season had ended, so we expected to measure a similar richness pattern as that observed in Huatulco.

Dominici-Arosemena and Wolff (2006) compared the numbers of fish species associated with coral ecosystems along the ETP and found the richest place to be the Galapagos Islands with 175 species (Edgar et al. 2004), followed by areas with intermediate numbers such as the Gulf of Papagayo with 78 species (Dominici-Arosemena et al. 2005), and those with lower numbers such as Manuel Antonio, Costa Rica, with 39 species (Phillips and Perez-Cruet 1984). In this sense, SJdS is a locality with intermediate numbers of reef fish species, very similar to the rest of upwelling areas along the ETP, with Labridae and Pomacentridae as the dominant families.

In the case of macroinvertebrates, SJdS is very similar to Salinas Bay, Costa Rica, where 14 species (6 echinoids, 2 holothuroids, 1 asteroid, 4 mollusks, and 1 crustacean; JJ Alvarado, unpubl data) have been recorded using the same methodology. In several sites along SJdS, we observed an intense catch of lobsters and sea cucumbers by hooka divers. The divers harvest juvenile individuals of lobsters and any species of sea cucumbers from under the rocks, altering the sea bottom on their exploration to extract the animals. This collection is made without any regulation or control by the authorities, and it is probably substantially reducing population abundances.

We recorded 28 additional macroalga species than the list published by Dawson (1962) for the Pacific coast of Nicaragua. The genera *Symploca, Ulva, Cladophora, Bryopsis, Chlorodesmis, Parvocaulis, Lithophyllum, Ceramium, Polysiphonia, Gelidiella, Peysonnelia, Champia, Wrangelia, Haloplegma,* and *Gracilaria* are first reports for the Pacific flora of this country. Most of the marine macroalgae in southern Nicaragua are turf-like and do not exceed 10 cm high. In many cases, turf patches are formed by *Chorodesmis* and by a combination of species from the Ceramiales, Gelidiales, and Dictyotales.

The benthic forms of *Sargassum* spp. (Phaeophyceae) are the most conspicuous species in our study area. It is common to observe large stands of these algae, often attached to rocks and dead coral, between depths of 1–6 m. As in other regions, these *Sargassum* stands in southern Nicaragua are probably perennial (Rivera and Scrosati 2006); during the dry season, when the upwelling of nutrients occurs, algae can reach more than 1 m high and can be a dominant component of the ecosystem in some areas. During the rainy season, biomass and coverage decreases, thalli are smaller and covered by epiphytes such as *Ulva* spp., and in many cases, with calcareous algae that attach throughout the cauloids and filoids, turning the stands pink. These forests are well recognized as critical habitats to be conserved because they provide refuge,

food, and nursery areas for numerous fishes and invertebrates (Aburto-Oropeza et al. 2007).

In Costa Rica, Cortés and Jiménez (2003) documented the presence of 13 species of coral (10 hermatypics and three ahermatypics) for the area of most intense upwelling, between Salinas Bay and the Murcielago Islands, while for the area of Culebra Bay, a marginal upwelling area, they noted the presence of 20 species of coral (16 hermatypics and four ahermatypics). Coral species number and composition in SJdS (nine hermatypics and four ahermatypics) are similar to Salinas Bay. On the Santa Elena Peninsula, Costa Rica, and at Murcielago Island, coral reefs are constructed primarily by *P. gigantea* and (at Murcielago) *P. panamensis* (Cortés 1997, Cortés and Jiménez 2003). In the Gulf of Panama, Maté (2003) recorded the presence of 20 species of corals, where *P. gigantea* played an important role as reef builder at greater depths (10–14 m).

Coral composition and cover is very similar between SJdS and Salinas Bay, Costa Rica, in contrast to the rest of the Gulf of Papagayo. In Salinas Bay, live coral cover is 2%–7%, with the principal coral species being *P. gigantea* and *P. panamensis* (JJ Alvarado, unpubl data). In contrast, the main reef-builders in Culebra Bay are *P. damicornis* (8% cover) and *P. elegans* (13% cover), with *P. gigantea* and *P. panamensis* accounting for only 0.04% and 1.6% of cover, respectively (Jiménez 2001). Based on these observations, we believe that the area between Santa Elena Peninsula and SJdS is a single geographical coral community unit because it shares the same number of coral species and composition dominated by *P. gigantea* and *P. panamensis*. However, the coral affinities of Nicaragua are more similar to that of the Central Mexican Pacific, being most similar to the state of Michoacan and having intermediate numbers of species (Fig. 4).

Along the ETP, there are two main types of reef structures: reefs in Mexico, Panama, Colombia, and some areas in Costa Rica and Ecuador are built by species of *Pocillopora* vs reefs dominated by the massive corals *Porites lobata* Dana, 1846 and *P. clavus*, such as off the islands of Cocos, Clipperton, and Galápagos (Cortés 2003). In this sense, the particularity of SJdS reef is that their main reef-builder is *P. gigantea*, breaking the pattern between *Pocillopora* or *Porites* reefs. The SJdS reefs are dominated by *P. gigantea*, probably because their polyps are larger than other species and remain open during the day. This enables the coral to take advantage of increasing food availability during the upwelling season and move sediments off with their tentacles during the rainy season.

As with corals in northern Costa Rica, the reefs of SJdS probably suffered intense mortality as a consequence of the Little Ice Age (Glynn et al. 1983). At SJdS, coral recovery has likely been slow because of the upwelling that occurs in this zone. Likewise, there are few protected areas on the coast (islands and bays) with conditions favorable for coral recruitment and reef development. Limits to the distribution of coral reefs are imposed by low sea water temperatures (< 18 °C) that negatively affect coral physiology and survival (Sheppard et al. 2009), reduce the ability of corals to feed (Mayer 1915 in Sheppard et al. 2009), reduce their ability to compete with other benthic organisms (Glynn and Steward 1973, Glynn and Ault 2000), and reduce rates of calcium carbonate deposition (Buddemeier and Smith 1999). The best coral development observed in this study was toward the north between Punta Gigante and Guacalito, and at El Toro, where there are small embayments and islands that protect the reefs from the wind and waves.

Localities in Nicaragua with high benthic diversity, such as Punta Gigante and Guacalito, offer a wider variety of habitats and resources for reef-associated species (Benfield et al. 2008). The greatest coral reef biodiversity in Nicaragua is located between these two localities, in an area of < 10 km². This high benthic diversity, coupled with both high fishing pressure on other coral reefs within the country and the lack of marine protected areas along the Pacific coast of Nicaragua, point to the need for management to assure the continuity of the coral biotopes of this region. The Punta Gigante-Guacalito unit should be protected to guarantee the spillover of commercial fishes and invertebrates to other parts of the coast and to preserve the most important coral communities along the Pacific coast of Nicaragua.

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