Rocky-reef fish assemblages at San José Island, Mexico

Asociaciones de peces de arrecifes rocosos en Isla San José, México.

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Abstract. We analyzed the composition, diversity, and abundance of marine fish at rocky reefs off San José island, Mexico between October 2001 and August 2002. Fish species were recorded using a visual census in 5 sampling areas of 50 by 5 meters at 2 depths, shallow (1-3 meters) and intermediate (5-7 meters). A total of 26 946 organisms were counted, belonging to 84 species. The families Serranidae (9 species), Labridae (8), Pomacentridae (7), and Haemulidae (6) were the most representative. We measured the rugosity of the bottom surface, which showed a positive relationship with abundance, richness, and fish diversity. The ocean bottom off San José island is covered with various size rocks that offer more feeding and refuge areas to fish assemblages than other areas. The ecological index increased during the warm season. Diversity and richness showed significant variations ($P<0.05$) by depth, with the highest values in exposed locations around the island (Conejo, Pardito, and San Francisquito). The biological value index indicated that the most representative fish species were *Stegastes rectifraenum, Abudefduf troschelii, Thalassoma lucasanum, Scarus ghobban,* and *Mulloidichthys dentatus.* The depth and wave exposure were the 2 environmental variables with the most influence on the structure of rocky-reef fish assemblages.

Key words: fish diversity, rocky reef, Baja California Sur, Gulf of California.

Resumen. Se analizó la estructura íctica de los arrecifes rocosos de Isla San José, México entre octubre del 2001 y agosto del 2002. Las especies fueron registradas por medio de censos visuales, los cuales se realizaron sobre transectos de 50 m de largo X 5 m de ancho en 2 profundidades: somera (1-3 m) e intermedia (5-7 m). Se contabilizaron un total de 26 946 individuos pertenecientes a 84 especies. Las familias mejor representadas fueron Serranidae (9), Labridae (8), Pomacentridae (7) y Haemulidae (6). La rugosidad del sustrato presentó una correlación positiva con la abundancia, riqueza y diversidad de especies de peces, lo que podría indicar que zonas con altos valores de rugosidad ofrecen a los peces más áreas de alimentación y refugio. Los índices ecológicos mostraron una tendencia de incremento de especies durante la temporada cálida. La diversidad y riqueza específica presentaron variaciones significativas (P<0.05), con valores más altos en los sitios expuestos de la isla (Conejo, Pardito y San Francisquito). El índice de valor biológico indicó que las especies más representativas fueron: *Stegastes rectifraenum, Abudefduf troschelii, Thalassoma lucasanum, Scarus ghobban* y *Mulloidichthys dentatus.* La profundidad y exposición al oleaje fueron las variables con mayor influencia en la estructura íctica de los arrecifes rocosos.

Palabras clave: diversidad de peces, arrecifes rocosos, Baja California Sur, golfo de California.

Introduction

Rocky reefs are complex coastal marine ecosystems with interactions between fish species. They are marine structures that offer greater protection to fish along the coast than in the open sea, allowing the development of ecosystems such as mangroves and sea grasses (Vázquez-Domínguez, 2000). Reefs are widely recognized as productive and heterogeneous biomes and consequently

have numerous associated species (Álvarez-Filip et al., 2006). In addition, reefs are well-known locations for economic activities , such as fishing (including of ornamental species) and tourism in various countries (Vázquez-Domínguez, 2000).

The Gulf of California recently has been ranked as sixth in the world's top 10 marine biodiversity "hot spots" for tropical reefs (Roberts et al., 2002; Campos-Dávila et al., 2005; Rodríguez-Romero et al., 2005). Some of the highest marine biodiversity values there are found on rocky reefs, which support a wide variety of endemic

species (Thomson et al., 2000).

San José island has rocky reefs along its coast with a high diversity of fish and is one of the largest islands in the southern Gulf of California. To date, there is no published detailed description of fish communities. The only information is from Sánchez-Ortíz et al. (1997), who studied the population densities and community structures of fish at 11 locations, including San Francisco Island (located close to San José Island), where they reported 101 fish species. In this work we describe the seasonal structure of fish assemblages associated with rocky reefs off San José Island.

Material and methods

San José Island is between 24°52´ and 25°06´ North latitude and between 110°43´ and 110°35´ West longitude (Bourillón-Moreno et al., 1991). It is of volcanic origin, 194-km² in area, and approximately 28 km long by 7.5 km wide. Its highest elevation is 633 m and in some areas it is covered with vegetation (Anonymous, 1987). Its coasts are quite steep on the eastern side, whereas on the west there are some creeks with small beaches in the interior, protected from winds. Bahía Amortajada on the southwestern coast has extensive sandy beaches and to the south is a mangrove area (Bourillón-Moreno et al., 1991) (Fig 1).

Six bimonthly samplings between October 2001 and August 2002 were made at 5 locations because of their extensive rocky reef coverage (Fig. 1). The 6 samplings were done during both cold and warm seasons because the Gulf of California has only these 2 distinct seasons yearly (Álvarez-Borrego and Schwartzlose, 1979; Anonimous, 2001). January, March, and May were in the cold season and June, August, and October in the warm season.

The visual census method was used because it is a nondestructive technique that provides both qualitative and quantitative descriptions of the reef-fish structure and is acceptable for studies concerning reef management and assemblage patterns (Bortone et al., 1991; Ackerman and Bellwood, 2000; Chávez-Comparan and Macías-Zamora, 2006).

Visual transects were made using free or scuba diving during daylight (10:00 to 16:00) over areas 50-m long and 5-m wide (250 m² per census). Censuses were done from fixed locations, with geographic positions recorded by a global positioning system (GPS) and a coastal mark. All species of fish and their observed abundances were recorded on acrylic sheets. At each selected location, 2 censuses with replicas were taken parallel to the coast at 2 depths, shallow (1-3 m) and intermediate (5-7 m).
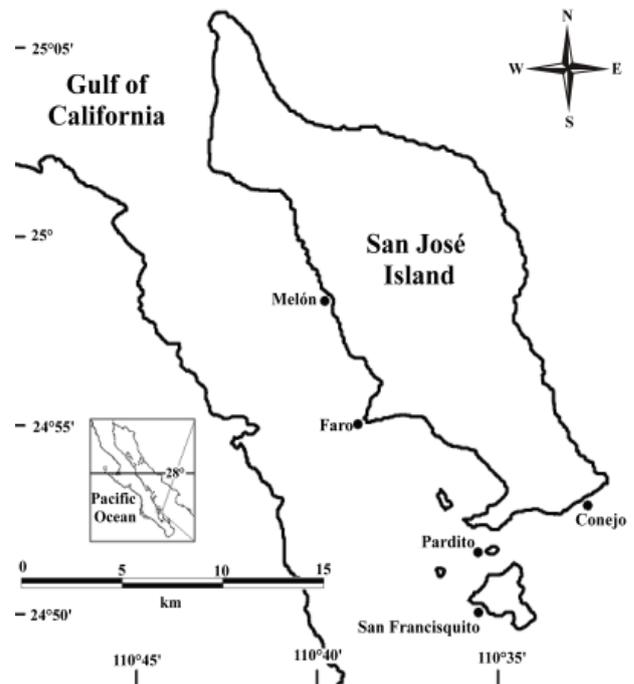

Figure 1. San José Island, showing the sample locations.

The density of organisms was obtained dividing the total number of individuals between the total samples surfaces.

Physiographic characteristics, such as water temperature, type of substrate, and rugosity were recorded at the sampling locations. The bottom was assessed visually to estimate the percentage coverage by rocks and sand and rugosity was determined by calculating the ratio L/l of the estimated real distance over the surface (L) to the straight line length or horizontal range (l) in the same vertical plane. To measure the real length, a chain was laid in a straight line over the bottom surface, allowing it to follow the projections and depressions (Luckhurst and Luckhurst, 1978). Measured rugosity has a minimum value of 1 for a flat bottom and increases with the degree of roughness of the bottom surface.

We use the following ecological indices based on species abundance: Shannon-Weaver's diversity (H´), was used to determine the change in the fish community structure. Given that the H´ value depends on species richness (number of species present in each sample) and evenness (index of Pielou, 1975), these values were also calculated.

An analysis of variance was used to determine differences in richness and diversity patterns between sites, season of the year, and depths (Clarke and Warwick, 1994). Where significant differences appeared, the Fisher

test (Zar, 1996) for multiple comparison was used to determine the pairs of averages that differed significantly. The numbers of individuals for all statistical analyses were log transformed (Log10 n + 1) to homogenize the variances and to normalize the distribution.

To determine the dominant species through the annual cycle, we used the Biological Value Index (BVI) proposed by Sanders (1960). To calculate this index, a value of importance, expressed in points, was assigned to each species as a function of its numerical abundance in each sample. This allows the species to be ranked in order of importance based on the spatio-temporal constancy of their abundance (Loya-Salinas and Escofet, 1990).

The similarity in the reef community structure of the different locations of the island was done using cluster analysis with the Q-mode matrix and an agglomerative-method complete linkage, using the fish species with 95% accumulated of relative abundance. The principal components were analyzed by each variable, using a Q-mode correlation matrix. The variables used in this analysis were depth, temperature, percentage of rock coverage, rugosity, species richness, abundance (square root transformed), and fish diversity .

Results

A total of 26,946 fish were recorded during 6 bimonthly samplings (15,261during the warm season and 11,685 in the cold season) from 84 species, 60 genera and 31 families (Table 1). The families most represented by number of species were Serranidae (9 species), Labridae (8), Pomacentridae (7), Haemulidae (6), Scaridae (5), Lutjanidae (4), and Muraenidae (4). The fish families of highest abundance were Pomacentridae (38 %), Labridae (18 %), and Haemulidae (10 %).

From 84 species identified, only 12 were recorded at all reefs and at both depths sampled. These common species off San José Island were *Abudefduf troschelii, Balistes polylepis, Bodianus diplotaenia, Canthigaster punctatissima, Fistularia commersonii, Holacanthus passer, Hoplopagrus guntheri, Lutjanus argentiventris, Mycteroperca rosacea, Scarus ghobban, Stegastes rectifraenum,* and *Thalassoma lucasanum.* The total fish density was of 0.89 organisms/m^2. In Table 2 we indicate the density values obtained by locations, season and depth.

The average sea temperature varied by season. The minimum temperature in the cold season was 18.5 ºC and the maximum was 31 ºC during the warm season. The rugosities in 5 locations were similar, but the highest values were at locations with intermediate depth (Table

3). There was a significant positive correlation between rugosity and fish abundance ($R = 0.678$, $P_{\alpha0.05}$ 0.031), richness ($R = 0.653$, $P_{\alpha0.05}$ 0.040), and diversity ($R = 0.700$, $P_{\alpha0.05}$ 0.024).

Three sampling locations had rock coverage of 80% or more. Whereas Pardito at the intermediate depth was 65% and San Francisquito at the same depth had 50%. The rock coverage was not correlated with abundance ($R = 0.285$, $P_{\alpha0.05}$ 0.424), richness ($R = 0.542$, $P_{\alpha0.05}$ 0.105), or diversity ($R = 0.535$, $P_{\alpha0.05}$ 0.110).

No significant variation was found in diversity or in specific richness between seasons ($P>0.05$), but they increased with the increase in the water temperature (Fig. 2a, 2b).

Diversity and species richness showed significant differences by depth, with higher values at intermediate depth. Among the different locations, the diversity was low in the Faro area and was significantly different from other locations (Faro-Conejo and Faro-Melon) (Table 4). Locations in exposed areas of the island (Conejo, Pardito, and San Francisquito) had higher values of richness and diversity at both depths (Table 5).

Four of all fish species found were 50% of the BVI; *S. rectifraenum, A. troschelii, T. lucasanum*, and *S. ghobban.* Similar results were found during the warm and cold seasons of the year, although higher dominance was observed in the cold season. In the cold season, 6 species (*A. troschelii, T. lucasanum, S. rectifraenum, Mulloidichthys dentatus, S. ghobban,* and *Paranthias colonus*) were 80% of the BVI, whereas in the warm season 8 species accounted for 80% (the 6 previous species plus *Microlepidotus inornatus* and *Haemulon maculicauda*).

The analysis of the 2 depths revealed that 4 species at the shallow depth were 50% of the BVI; *S. rectifraenum, A. troschelii, T. lucasanum*, and *S. ghobban*, whereas at the intermediate depth, 5 species were 50% (the 4 previous species and *M. dentatus*) (Fig. 3).

A cluster analysis distinguished 3 groups. The first was at the shallow depth at 5 sites. Of these Faro was the most remote. The second group was made up of the sites Faro and Melón (intermediate depth)**,** which are located in protected areas of the island. Group 3 included Conejo, San Francisquito, and Pardito, all at the intermediate depth but located at exposed areas of the island (Fig. 4).

The principal component analysis showed that 2 components were 84% of the variance. The first component explained 73% of the variance associated with the spatial distribution of species abundance, where the depth was the dominant variable. The shallow locations are located on the right side of figure 5 and the intermediate depth locations on the left side. The second component explained 10% of the variance and no variables dominated as they did in the

Table 1. List of fish species recorded during the visual transects by locations and 2 depths [DS = shallow (1-3 m) and DI = intermediate (5-7 m)]

Species	Melon		Faro		Conejo		San Francisquito		El Pardito	
	DS	DI	DS	DI	DS	DI	DS	DI	DS	DI
Abudefduf troschelii	X	X	X	X	X	X	X	X	X	X
Balistes polylepis	X	X	X	X	X	X	X	X	X	X
Bodianus diplotaenia	X	X	X	X	X	X	X	X	X	X
Canthigaster punctatissima	X	X	X	X	X	X	X	X	X	X
Fistularia commersonii	X	X	X	X	X	X	X	X	X	X
Holacanthus passer	X	X	X	X	X	X	X	X	X	X
Hoplopagrus guntheri	X	X	X	X	X	X	X	X	X	X
Lutjanus argentiventris	X	X	X	X	X	X	X	X	X	X
Mycteroperca rosacea	X	X	X	X	X	X	X	X	X	X
Scarus ghobban	X	X	X	X	X	X	X	X	X	X
Stegastes rectifraenum	X	X	X	X	X	X	X	X	X	X
Thalassoma lucasanum	X	X	X	X	X	X	X	X	X	X
Diodon holocanthus	X	X	X	X	X	X	X	X		X
Kyphosus analogus	X	X		X	X	X	X	X	X	X
Mulloidichthys dentatus	X	X	X	X		X	X	X	X	X
Sufflamen verres	X	X		X	X	X	X	X	X	X
Gymnothorax castaneus		X	X	X	X	X	X	X		X
Halichoeres dispilus		X	X	X	X	X	X	X		X
Mugil cephalus	X	X	X	X	X	X	X	X		
Nicholsina denticulada	X	X	X	X		X	X	X	X	
Serranus psittacinus	X	X	X	X		X	X	X		X
Anisotremus interruptus	X	X		X	X		X	X		X
Cephalopholis panamensis	X	X	X	X		X		X		X
Cirrithus rivulatus			X		X	X	X	X	X	X
Haemulon sexfasciatum		X		X	X	X	X	X		X
Johnrandallia nigrirostris		X			X	X	X	X	X	X
Lutjanus novemfasciatus	X	X	X	X	X		X	X		
Microspathodon dorsalis		X	X		X		X	X	X	X
Paranthias colonus		X	X			X	X	X	X	X
Prionurus punctatus	X	X		X		X	X	X		X
Scarus perrico	X	X	X				X	X	X	X
Halichoeres chierchiae		X			X	X	X	X		X
Halichoeres nicholsi		X		X		X	X	X		X
Halichoeres semicinctus				X	X	X	X	X		X
Alphestes immaculatus	X	X		X	X			X		
Chaetodon humeralis		X	X	X				X		X
Chromis atrilobata					X	X		X	X	X
Cirrhitichthys oxycephalus	X					X		X	X	X
Scarus compressus	X					X		X	X	X
Scarus rubroviolaceus	X	X				X	X			X
Thalassoma grammaticum				X	X	X	X			X
Urobatis concentricus		X		X	X	X	X			X
Caranx caballus		X				X		X		X
Epinephelus labriformis		X				X		X		X

Table 1. Continues

Species	Melon DS	Melon DI	Faro DS	Faro DI	Conejo DS	Conejo DI	San Francisquito DS	San Francisquito DI	El Pardito DS	El Pardito DI
Gerres cinereus		X	X	X	X					
Microlepidotus inornatus		X	X	X			X			
Muraena lentiginosa		X	X		X					X
Ophioblennius steindachneri			X		X		X		X	
Pomacanthus zonipectus		X	X	X		X				
Sargocentron suborbitalis		X	X	X					X	
Urobatis halleri	X		X	X					X	
Alphestes multiguttatus		X			X		X			
Arothron meleagris					X	X			X	
Kyphosus elegans						X	X		X	
Lutjanus viridis		X				X			X	
Stegastes flavilatus					X	X	X			
Apogon retrosella						X				X
Echidna nebulosa								X		X
Girella simplicidens			X	X						
Haemulon flaviguttatum		X		X						
Haemulon maculicauda		X		X						
Myripristis leiognathus			X	X						
Pseudobalistes naufragium					X	X				
Serranus fasciatus				X		X				
Acanthurus nigricans									X	
Acanthurus xanthopterus		X								
Apogon pacifici										X
Dasyatis brevis						X				
Diplobatis ommata										X
Gymnomuraena zebra								X		
Haemulon steindachneri				X						
Halichoeres notospilus					X					
Hemirhamphus saltator							X			
Labrisomus xanti			X							
Microspathodon bairdii							X			
Paralabrax maculatofasciatus				X						
Pareques viola		X								
Rypticus bicolor							X			
Sphoeroides lobatus				X						
Sphyraena lucasana						X				
Stegastes leucorus								X		
Trachinotus rhodopus						X				
Tylosurus acus pacificus					X					
Caranx caninus						X				

first component (Fig. 5).

In the fish assemblages, the first component, the depth and richness eigenvectors, were more negative, whereas the temperature was more positive. In the second component, the rock coverage and rugosity yielded values on the positive side of Figure 5, whereas the abundance and depth were negative. The separation of Conejo at the intermediate depth, in the upper left of the figure

Table 2. Calculated density of fishes in San José Island, by locations, season and depth

	Number of fish	*Area (m²)*	*Total area (m²)*	*Density*
Locations				
Pardito	6618	250	6000	1.1030
Faro	5676	250	6000	0.9460
San Francisquito	4902	250	6000	0.8170
Conejo	4878	250	6000	0.8130
Melon	4872	250	6000	0.8120
Season				
Cold	11685	250	15000	0.7790
Warm	15261	250	15000	1.0174
Depth				
Shallow (1-3m)	10015	250	15000	0.6677
Intermediate (5-7m)	16931	250	15000	1.1287
Total	26946	250	30000	0.8982

Figure 2. a, variation in specific richness vs. water temperature; b, variation in diversity vs. evenness.

5, is caused mainly by the high values of richness (51) and rugosity (1.44). The grouping in shallow locations is mainly caused by their similar water temperatures.

Discussion

At San José Island there is less influence from tourism than at Espiritu Santo and Cerralvo Islands in the lower Gulf of California, and therefore less disturbance to these fish associations. which makes San José Island an ecologically and economically important location. We found that from 19 ornamentally important fish species reported by Almenara-Roldán (2000) in the Gulf of California, 12 species (63%) were found here.

The depth was the most influential variable in the structure of fish assemblages around this island, where the specific richness, diversity, and abundance increased with depth. This variable was the only one of all the ecological indices analyzed that showed significant variation. Other studies on reef-fish communities in the Gulf of California also found a positive relationship between species richness, abundance, diversity, and depth (Sánchez-Ortiz et al., 1997; Arreola-Robles and Elorduy-Garay, 2002; Sala et al., 2002; Rodríguez-Romero et al., 2005; Álvarez -Filip et al., 2006).

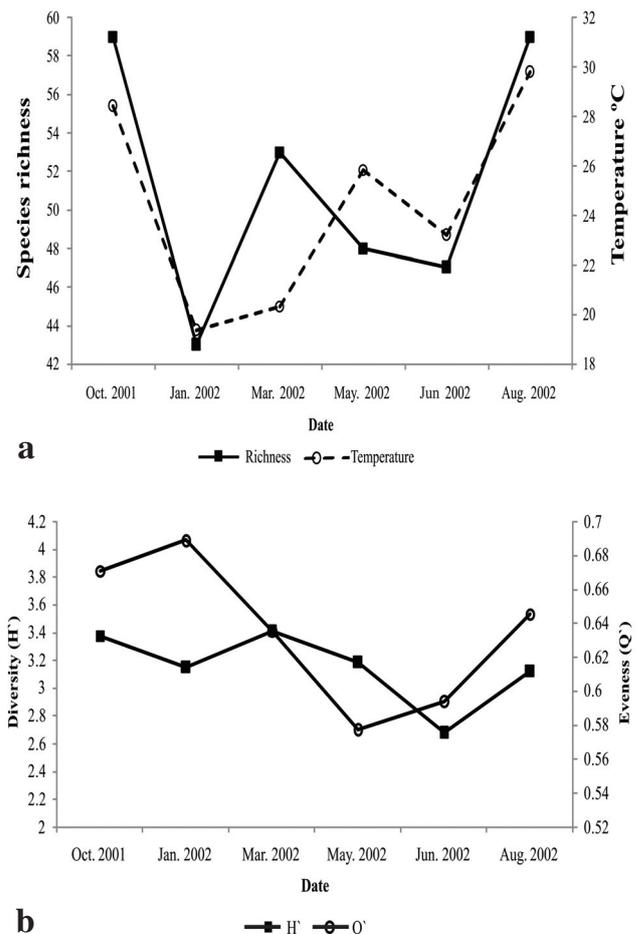The changes observed in the fish assemblages with depth could be related to visiting fish species at the intermediate depth. These species were seen only once at 1 location. Some pelagic species were found at this intermediate depth (*Caranx caballus, Caranx caninus,* and *Sphyraena lucasana* among others) that were not seen at the shallow depth. Another factor that could have influenced this result was the bottom rugosity, which was generally higher at the intermediate depth. Other studies have found that rugosity adds complexity to the habitat, resulting in more feeding areas for fish assemblages and refuge in caves and cracks (Anderson et al., 1989; Aburto-Oropeza and Balart-Páez, 2001).

The only location that had significant variation in ecological indices compared to others was Faro, maybe because of its particular depth characteristics. This location is very shallow, with a maximum depth of 4.6 m, and is found between 2 sandy areas, which would explain the low fish diversity. Some fish species characteristic to this location with a sandy bottom were

Table 3. Habitat description in the 5 locations at San José Island, Gulf of California

Habitat descriptors	Locations									
	Conejo		Faro		Melón		Pardito		San Francisquito	
Depth (meters)	6	1.5	6	1.5	6	1.5 m	6	1.5 m	6	1.5
Rugosity	1.44	1.12	1.15	1.12	1.29	1.10	1.17	1.17	1.25	1.06
Percentage cover sand	10	5	20	5	15	0	35	0	50	5
Percentage cover rocks	90	95	80	95	85	100	65	100	50	95
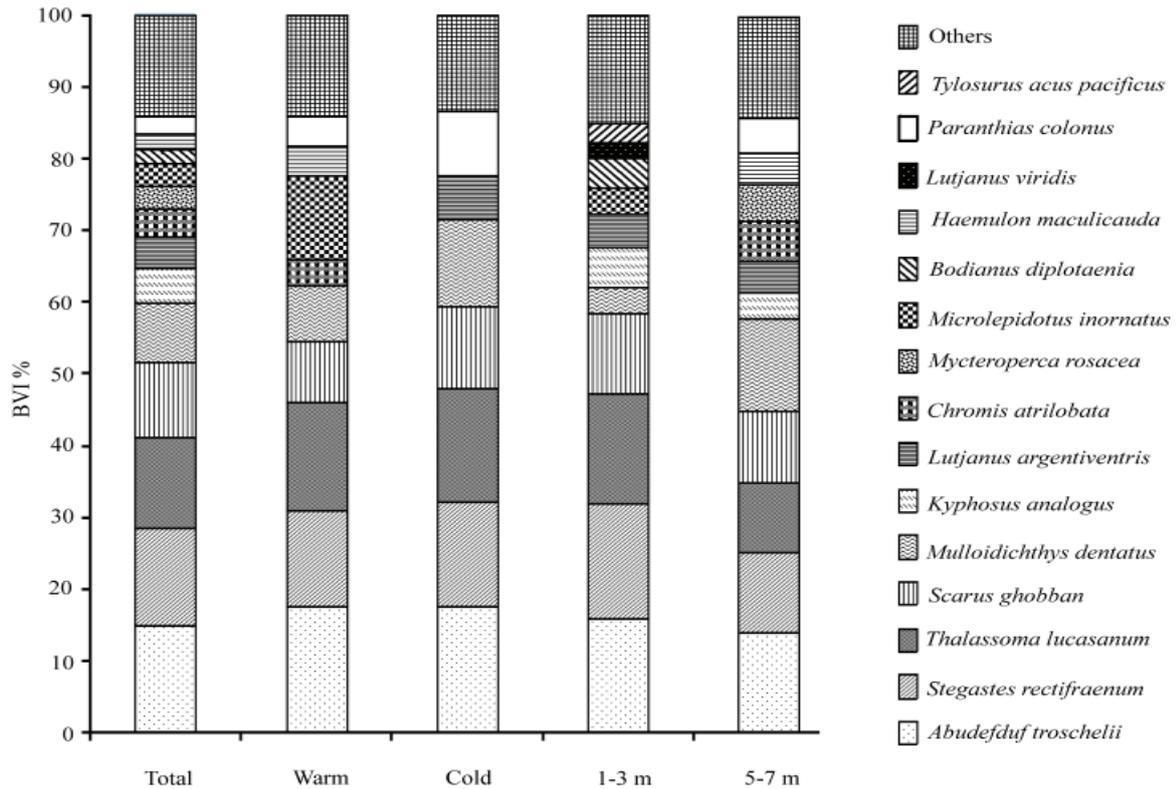
Figure 3. Index of Biological Values (BVI) by locations and main fish species around San José Island

**Table 4.** The Fisher test applied to 5 locations of San José Island. *= significant difference

Loc.	Conejo	Melon	San Franc.	Faro	Pardito
Con.		0.3809	0.80052	0.01016*	0.87733
Mel.	0.3809		0.05015	0.00022*	0.07129
S. F.	0.07129	0.05015		0.1165	0.99983
Faro	0.01016*	0.00022*	0.1165		0.08374
Pard.	0.87733	0.07129	0.99983	0.08374	

Haemulon steindachneri, *Paralabrax maculatofasciatus*, and *Sphoeroides lobatus*, which were found at Faro but at no other location. Also *Mugil cephalus*, *Mulloidichthys dentatus*, and *Microlepidotus inornatus* were found to be more abundant at this location with its sandy areas.

Grouping and ordering analysis determined that the fish association structure at San José Island is influenced mainly by depth. However, strong currents also must influence the presence of some species in locations as the San José channel, where Faro and Melón are. The locations Conejo, Pardito, and San Francisquito have weaker currents and are exposed to tides. We have not

Table 5. Diversity, evenness, and richness values at 2 depths and standard deviation at each location of San José Island

| | Diversity | | Eveness | | Richness | |
| | Depth | | Depth | | Depth | |
Locations	Shallow	Intermediate	Shallow	Intermediate	Shallow	Intermediate
Conejo	2.39 ± 0.334	3.14 ± 0.787	0.62 ± 0.090	0.69 ± 0.102	38	51
Faro	1.75 ± 0.793	2.46 ± 0.631	0.46 ± 0.174	0.59 ± 0.127	36	45
Melon	2.12 ± 0.706	2.84 ± 0.304	0.60 ± 0.167	0.63 ± 0.070	28	49
Pardito	2.61 ± 0.430	2.94 ± 0.396	0.66 ± 0.084	0.66 ± 0.090	32	46
San Francisquito	2.60 ± 0.338	2.95 ± 0.368	0.64 ± 0.045	0.66 ± 0.087	43	45
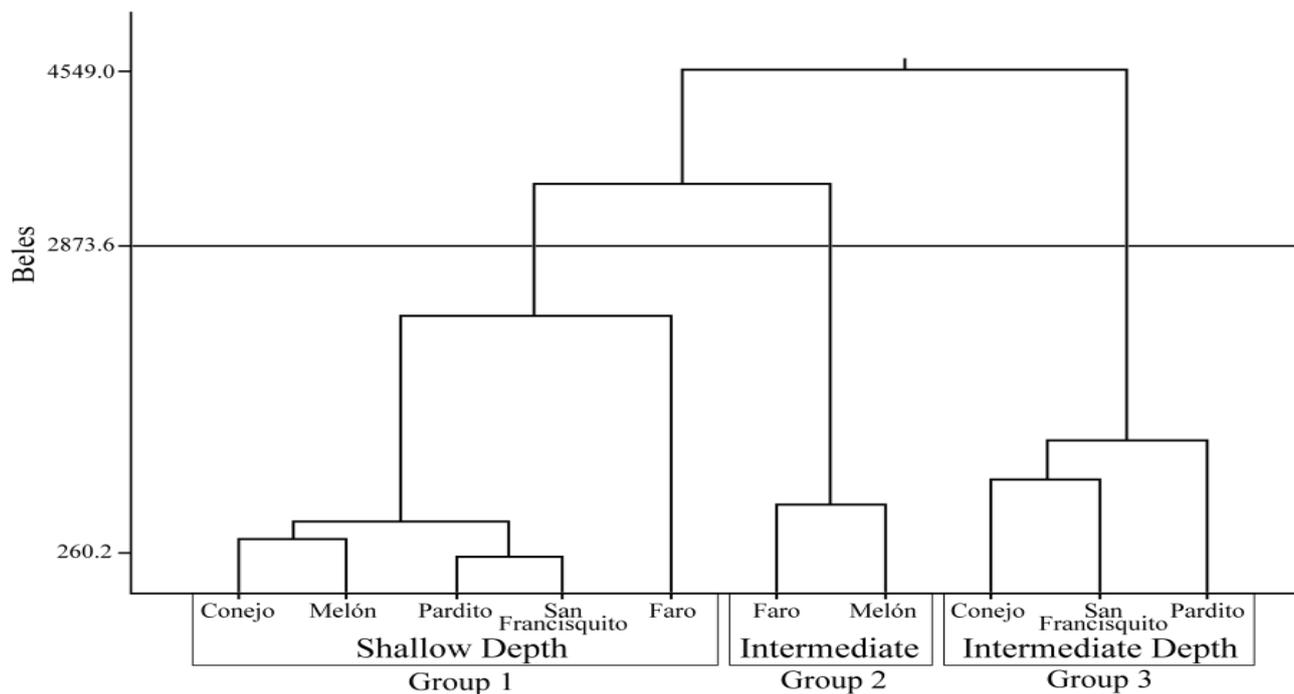
Figure 4. Classification analysis by locations in 2 depths in Isla San José

compared the effect of tides and currents on fish species abundance. However, there are studies that indicate the influence of these factors on the reef-fish assemblages (Aburto-Oropeza and Balart, 2001; Carleton et al., 2001; Friedlander et al., 2003).

The locations with the highest diversity and richness were those exposed to tides, but with weak currents (Conejo, Pardito, and San Francisquito). This was found at both depths studied and is consistent with Friedlander et al. (2003) on the reef-fish associations of Hawaii, who observed that areas moderately exposed to tides had greater richness and diversity. In a study done at the Australian barrier reef, Carleton et al. (2001) also determined that

locations with weak currents have more prerecruit fish than those with strong currents.

Some fish species found only in exposed locations belong to the family Pomacentridae (*Chromis atrilobata, Stegastes flavilatus, Stegastes leucorus, Microspathodon bairdii*). They use these areas for feeding. *Chromis atrilobata* and species of the genus *Stegastes* have been reported as planktivores and herbivores (Allen and Robertson, 1994; Chávez-Comparan and Macías-Zamora, 2006) and need very productive areas or those with oceanographic features that retain this food type. These species have pelagic larvae and are drawn by the currents to these areas. Other species found in the exposed areas
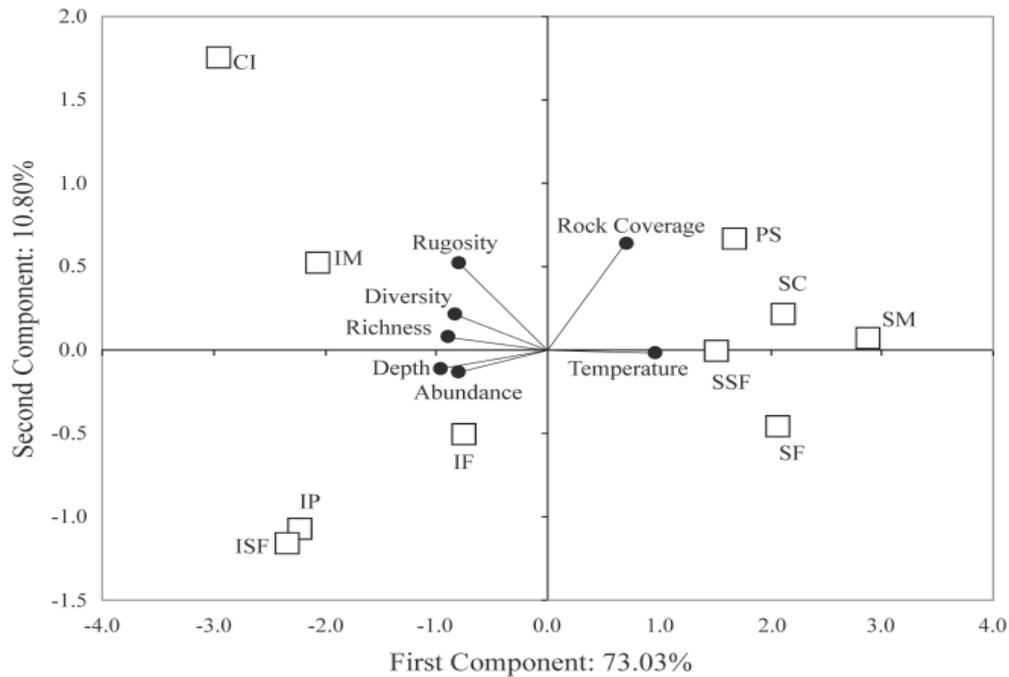
Figure 5. Principal component analysis of variables. IM = intermediate Melon, SM = shallow Melon, IP = intermediate Pardito, SP = shallow Pardito, IF= intermediate Faro, SF = shallow Faro, ISF = intermediate San Francisquito, SSF = shallow San Francisquito. Also shown the projections of variables; rock coverage, temperature, rugosity, richness species, abundance, and diversity of the sampling locations.

were *C. caninus* and *Trachinotus rhodopus* of the family Carangidae, which also have pelagic larvae.

The fish species *S. rectifraenum, T. lucasanum*, and *Scarus ghobban* had a higher dominance in the shallow depth than in the intermediate depth. *M. dentatus* was one of the most dominant species at the intermediate level, probably because of their preference for areas with mixed patches of sand and rocks, a characteristic that is found at greater depths. This species forms small schools and feeds on small fish and other organisms, including worms, shrimp, crabs, mollusks, polychaetes, and echinoderms that live in the sand. With the aid of chemosensory organs in their chin barbels they locate their prey (Allen and Robertson, 1994; Thomson et al., 2000).

Another fish species determined as dominant at 5 to 7 m, which appeared only rarely at 1 to 2 m, was *C. atrilobata*. This species was never observed at the protected sites Melón and Faro and was found with greater abundance and frequency at Conejo at intermediate depth. They prefer relatively deep areas between 6 and 20 m, although occasionally are found in deeper waters (Thomson et al., 2000).This species prefers areas with abundant plankton, which constitutes its food, and probably appears in these areas during high tide (Arreola-Robles and Elorduy-Garay, 2002; Chávez-Comparan and Macías-Zamora, 2006). The fish species that were found only in 1 or 2 locations show that the reefs are visited or used as transit areas by some species.

From 84 fish species reported in rocky reefs at San José island, only 12 (14%) were found at 5 locations and both depths, which indicates that the fish composition of each location varies according to its particular characteristics. A similar observation was made by Villareal-Cabazos et al. (2000) at the coral reef of Cabo Pulmo in Baja California Sur. The habitat of reef-fish communities in the Gulf of California are structured by depth, with different structural associations at depths of 0 to 4 m and 5 to 19 m. The upper limit of the second category was established by Allen and Robertson (1994), who mentioned 3 depths.

Richness, abundance, diversity, and evenness increase with water temperature, which is consistent with reports about the Gulf of California by Rodríguez-Romero et al. (1994), Pérez-España et al. (1996), Aburto-Oropeza and Balart-Páez (2001), Campos-Dávila et al. (2005), and Rodríguez-Romero et al. (2005). This increase during summer associated with winds from the southwest (Roden, 1964) generates an increase in the amount of food available and a higher abundance of fish. During winter, the northwest winds on the east coast of the Gulf affect the number of species in the Gulf, which begins to decline (Pérez-España et al., 1996).

During June 2002, a reduction in the ecological indices was measured and was associated with a 2.6 ºC decrease in temperature from the previous sampling month. With this change in temperature, the fish spend less energy on motor activities because of their ectothermic metabolism (Eckert et al., 1991) and with reduced mobility, they become less visible to divers.

The dominant fish species in these associations may remain constant in time, which has been mentioned by Castro-Aguirre et al. (1995), who wrote that rocky reef fish communities in the Gulf of California are relatively homogenous because the resources and protection offered by the Gulf of California are constant.

Acknowledgements

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