

ARTICLE

Comparison of ecological diversity and species composition of macroalgae, benthic macroinvertebrates, and fish assemblages between two tropical rocky reefs

Comparación de la diversidad ecológica y composición de especies de ensambles de macroalgas, macroinvertebrados bentónicos y peces en dos arrecifes rocosos tropicales

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Resumen.- En el medio marino, las costas rocosas son reconocidas por su alta diversidad de especies y particularmente las zonas de transición representan áreas de mezcla biótica, provocado por las variaciones naturales históricas y ecológicas que permiten la presencia de taxones de diferentes regiones y que presentan rasgos biológicos diferentes. Un estudio intensivo permitió describir los ensambles de macroalgas, macroinvertebrados (moluscos, crustáceos y equinodermos) y de peces en dos arrecifes rocosos: Islas Marietas y Tehuamixtle, en la zona de transición tropical-templado en el norte del Pacífico de México, utilizando índices ecológicos tradicionales (riqueza, diversidad y uniformidad) y complementando con índices de distinción taxonómica. Se colectó el material biológico de 10 cuadrantes (25 × 25 cm) ubicados aleatoriamente a lo largo de dos transectos de 50 m paralelos a la línea de costa, a una profundidad de entre 6 y 12 m. Se identificaron 204 especies: 22 macroalgas, 55 moluscos, 78 crustáceos, 11 equinodermos y 38 peces. La estructura de la comunidad de macroalgas, macroinvertebrados y peces fue similar entre los sitios. Macroalgas, moluscos y peces fueron más diversos en verano y crustáceos y equinodermos fueron más diversos en el invierno. Los resultados y la literatura sugieren un patrón latitudinal de menores cambios estacionales en equinodermos y crustáceos en las altas respecto a bajas latitudes en el Pacífico mexicano.

Palabras clave: Biodiversidad, macrobentos, arrecifes rocosos, distintividad taxonómica

Abstract.- Within the marine environment, the rocky shores are recognized for their high species diversity and particularly transitional zones represent areas of biotic mix, promoted by historical and ecological natural variations that allow the presence of taxa from different regions and which present dissimilar biological traits. An extensive survey describes the benthic macroalgae, macroinvertebrates (molluscs, crustaceans, and echinoderms), and fish assemblages at two rocky reefs, Islas Marietas and near Tehuamixtle, in a tropical-temperate transitional zone in the Pacific waters of central Mexico using traditional ecological indices (richness, diversity, and evenness) and complementary taxonomic distinctness indices. Biological material inside each of ten randomly-chosen quadrants (25 × 25 cm) placed along two 50 m transects oriented parallel to the coastline, between 6 and 2 m depth was collected. From field collections, 204 species were identified: macroalgae (22), molluscs (55), crustaceans (78), echinoderms (11), and fish (38). The structure of macroalgae, macroinvertebrates and fishes was similar between sites. Species of macroalgae, molluscs, and fishes were more diverse in summer; crustaceans and echinoderms were more diverse in winter. Our results and the literature suggest a latitudinal pattern of lower seasonal changes in echinoderms and crustaceans at high latitudes, as compared to southern regions of the Mexican tropical Pacific.

Key words: Biodiversity, macrobenthos, rocky reefs, taxonomic distinctness

INTRODUCTION

Rocky shores are widely recognized for their high species diversity; they are among the best understood marine ecosystems, concentrating many descriptive and

experimental scientific works (Dayton 1971, Menge 1976, Wootton 1993, Underwood 2000). Rocky reefs are complex environments with benthic assemblages of flora and fauna

showing high heterogeneity in their composition and structure at different scales of time and space (Kaehler & Williams 1998), and immerse in diverse interactions such as predation and competition for food and space (Menge 1976, Dayton & Tegner 1984, Underwood & Chapman 1998).

Transitional zones are the boundaries between climatic realms, in this case the tropical and subtropical. This situation results in strong seasonality, as the tropical conditions tend to prevail during the summer and subtropical during the winter. In the ocean, they represent areas of biotic mix, promoted by historical and ecological natural variations that allow the presence of taxa from different regions and which present dissimilar biological traits (Zajac *et al.* 2003, Morrone 2009, Anderson *et al.* 2012). These zones deserve special attention because they commonly correspond to boundaries between biogeographic regions, typically in the scale of thousands of kilometers, where intense biotic interactions occur (Ruggiero & Ezcurra 2003, Anderson *et al.* 2012).

In the northern part of the Mexican tropical Pacific, the study of rocky reefs benthic communities has been mostly devoted to the collection of basic information about the distribution and abundance of particular taxonomic groups and only few examples exist where these systems are analyzed at the ecosystem level (CONANP 2007). Species composition and abundance of macroalgae (Enciso-Padilla & Serviere-Zaragoza 2006), molluscs (Ríos-Jara *et al.* 2006), crustaceans (Gasca 2009), echinoderms (Ríos-Jara *et al.* 2008, 2013) and fishes (Castro-Aguirre *et al.* 2006, Chávez-Comparán *et al.* 2006) have independently shown that this area is inhabited by species from different biogeographic domains, namely the Gulf of California, the Eastern Tropical Pacific, and even some temperate species that move southward during the winter (Robertson & Allen 2008).

Our objective was to compare the structure and composition of benthic flora, macroinvertebrates, and fish assemblages at two rocky reefs located in the transitional area between the tropical and subtropical northeastern Pacific, using traditional ecological indices (richness, diversity, and evenness) as well as taxonomic distinctness indices (which offer complementary information), to test the hypothesis that because of the strong seasonality that exists in these type of transitional systems, all taxonomic groups would show very intense seasonal differences in species composition and dominance.

MATERIALS AND METHODS

STUDY SITES AND SAMPLING

We studied 2 sites from the Bahía de Banderas, Mexico area: Islas Marietas and near Tehuamixtle (Fig. 1), these areas are located between the Cortes and Mexican biogeographic provinces (Briggs 1974). Both sites show rocky reefs at depths of 6 to 12 m. Main differences between sites include physiographic conditions and the environmental protection status; Islas Marietas is considered a RAMSAR area, while Tehuamixtle receives no specific conservation efforts.

The mesoscale ocean circulation is determined by the convergence of three ocean current systems: (a) the cold California Current flowing to the Southeast, (b) the warm Costa Rica Current, flowing northward, and (c) the warm water from the Gulf of California that reaches the area during fall and winter (Badán 1997). Strong annual amplitude in the climate signal results in well-defined winter and summer seasons (CNA 2012). We recorded *in situ* water temperatures along an annual cycle using HOBO sensors, located at 6 m depth and programmed to register every 30 min, registering monthly mean values between 19.4°C in February and 29.7°C in July (unpublished data). Salinity near the coastline is strongly affected by rivers runoff and seasonal precipitation; a rainy period during June to October and a dry period during the rest of the year (November to May; Hernández-Herrera *et al.* 2005). Long term, low resolution water temperature data (Reynolds *et al.* 2012), also showed a well-defined seasonal cycle.

STRUCTURE OF THE ASSEMBLAGES AND STATISTICAL ANALYSIS

To cover both spatial and temporal differences, Islas Marietas and Tehuamixtle were visited 2 times during the summer (September 2010 and July 2011) and also twice in winter (December 2010 and March 2011). At each visit, we collected by hand (scuba-diving) all macroalgae, molluscs, crustaceans, and echinoderms specimens inside each of ten randomly-chosen quadrants (25 × 25 cm) placed along two 50 m transects oriented parallel to the coastline, at two depths 6-9 m and 9-12 m depth (n= 20), for a total of 160 quadrants. The specimens were placed in labeled plastic bags and preserved in a 0.10 formalin-seawater (1:9) solution.

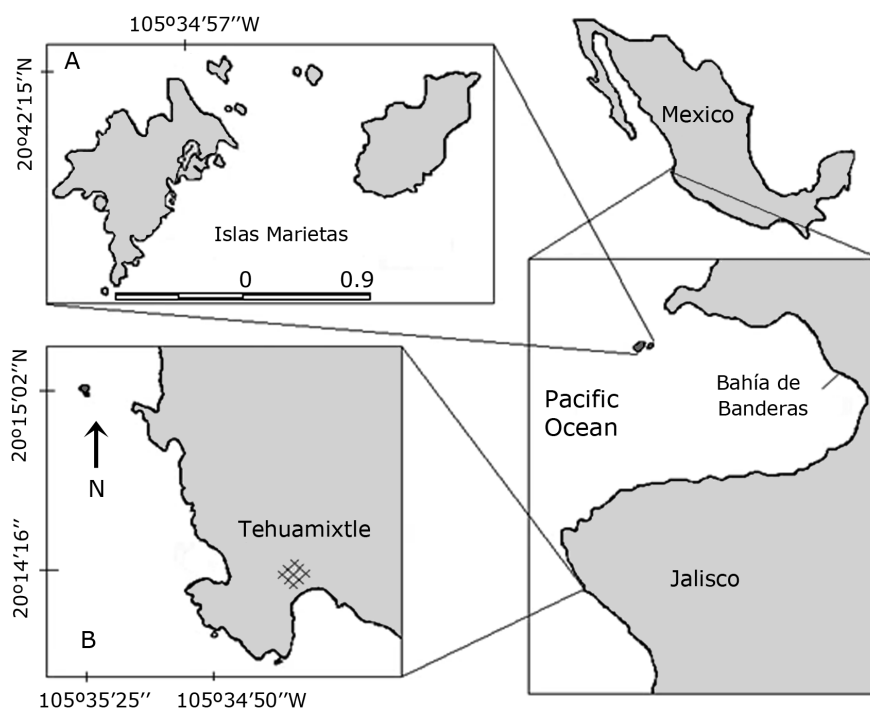


Figure 1. Study sites. (A) Islas Marietas in the State of Nayarit and (B) Tehuamixtle in the State of Jalisco / Sitios de estudio. (A) Islas Marietas en el Estado de Nayarit y (B) Tehuamixtle en el Estado de Jalisco

For fishes, 2 videos were taken along the 50×2 m belt transects at each site and visit. In the videos, a diver filmed the fishes observed along the belt transect, during periods ranging between 4 to 5 min, depending on the habitat complexity and the environmental conditions. The videos were later revised to count all individuals and identify the species in the entire sampled area (100 m^2).

In the laboratory, we weighted the fronds of each macroalgae sample ($\pm 0.1 \text{ g}$), and counted all molluscs, crustaceans, and echinoderms. All samples were identified to the lowest possible taxonomic level.

To confirm the completeness of the species inventory we applied Jackknife 1 and Bootstrap statistical tests using PRIMER-6 software (PRIMER-E, Ivybridge, UK; Clarke & Gorley 2006). To describe the community structure for each group and sample, we computed classic descriptors: species richness (S), abundance (N ; total wet weight in grams for the macroalgae, and total number of molluscs, crustaceans, echinoderms, and fish individuals),

Shannon-Wiener diversity index (H'), and evenness (J'). Also, we estimated average taxonomic distinctness (Δ^+) and variation in taxonomic distinctness (Λ^+) at each transect, based on presence-absence records. These measures provide a summary of the relatedness between organisms and incorporate the identity of species from a sample by considering the average path length between all pairs of species, measured through a Linnaean classification tree. The Δ^+ index requires only a species list for calculation and a detailed taxonomic classification. It is unbiased to differences in species richness, and to sampling effort (Clarke & Warwick 1998).

For Δ^+ and Λ^+ , taxonomic trees were prepared to include macroalgae, molluscs, crustaceans, echinoderms, and fish at all taxonomic levels. The classifications were based on Algaebase¹, the International Taxonomic Information System² for macroinvertebrates, and Nelson (2006) for fish. When a higher taxonomic category was non-existent in a particular species (*i.e.*, suborder or subfamily), we

¹<www.algaebase.org>

²<www.itis.gov>

assigned dummy names for the taxa that needed it, in order to standardize the topology tree and have a common format. All analyses of taxonomic diversity were performed using PRIMER-6 software (PRIMER-E, Ivybridge, UK; Clarke & Gorley 2006) and assuming proportional weight to each higher taxonomic level.

Once the values of all indices were calculated, we used a permutational multivariate analysis of variance (PERMANOVA; Anderson 2001) to determine the community structure differences for macroalgae, molluscs, crustaceans, echinoderms, and fishes, analyzing each

taxonomic group independently, and using sites and seasons as factors. Later, the Bray-Curtis coefficient was used to compare composition similarity between sites and seasons and a non-metric multidimensional scaling (NMDS) ordination based on the full matrix was built to graphically represent the assemblage's patterns. As a complement, we used the SIMPER test (dissimilarity percentage analysis; calculated with PRIMER-6) to identify those species that contributed the most to the qualitative differences found between sites and seasons.

Table 1. PERMANOVA based on Bray-Curtis dissimilarities of S, richness; N, wet weight in grams for the macroalgae, and number of individuals; J', Pielou's evenness; H', Shannon-Waver diversity; Δ^+ , average taxonomic distinctness; Λ^+ , variation in taxonomic distinctness of macroalgae, molluscs, crustaceans, echinoderms and fish at 2 sites during 2 seasons in the southeastern Gulf of California. IM= Islas Marietas, TE= Tehuamixtle. (* $P < 0.05$; ** $P < 0.01$) / PERMANOVA basado en la disimilaridad de Bray-Curtis de la S, riqueza; N, biomasa en gramos de peso húmedo para macroalgas y número de organismos; J', equidad de Pielou; H', diversidad de Shannon-Waver; Δ^+ , promedio de distintividad taxonómica; Λ^+ , variación de distintividad taxonómica de macroalgas, moluscos, crustáceos, equinodermos y peces en 2 sitios durante 2 estaciones al sureste del Golfo de California. IM= Islas Marietas, TE= Tehuamixtle. (* $P < 0,05$; ** $P < 0,01$)

Index	Sites			Seasons			Sites X season		
	F	P	d.f.	F	P	d.f.	F	P	d.f.
Macroalgae									
S	2.82	0.072	1, 159	8.86	0.005**	1, 159	0.95	0.330	1, 159
N	2.37	0.063	1, 159	6.39	>0.01**	1, 159	2.31	0.066	1, 159
H'	0.78	0.403	1, 159	9.88	>0.01**	1, 159	0.77	0.405	1, 159
J'	0.69	0.439	1, 159	9.85	0.001**	1, 159	0.77	0.404	1, 159
Δ^+	0.74	0.410	1, 159	10.52	>0.01**	1, 159	0.98	0.313	1, 159
Λ^+	0.36	0.662	1, 159	9.91	>0.01**	1, 159	0.37	0.655	1, 159
Molluscs									
S	0.62	0.455	1, 159	18.51	>0.01**	1, 159	0.33	0.627	1, 159
N	4.69	0.015**	1, 159	0.87	0.394	1, 159	2.90	0.066	1, 159
H'	3.62	0.058	1, 159	0.36	0.604	1, 159	0.85	0.365	1, 159
J'	3.66	0.053	1, 159	0.40	0.556	1, 159	0.85	0.381	1, 159
Δ^+	0.04	0.931	1, 159	28.70	>0.01**	1, 159	0.55	0.447	1, 159
Λ^+	1.72	0.152	1, 159	9.38	>0.01**	1, 159	1.27	0.274	1, 159
Crustaceans									
S	0.36	0.698	1, 159	6.35	0.003**	1, 159	1.13	0.301	1, 159
N	0.47	0.694	1, 159	6.99	>0.01**	1, 159	1.03	0.354	1, 159
H'	0.32	0.617	1, 159	10.54	0.001**	1, 159	0.34	0.601	1, 159
J'	0.15	0.783	1, 159	10.66	>0.01**	1, 159	0.43	0.536	1, 159
Δ^+	0.03	0.895	1, 159	11.67	>0.01**	1, 159	0.22	0.683	1, 159
Λ^+	0.83	0.385	1, 159	10.57	>0.01**	1, 159	0.83	0.391	1, 159
Echinoderms									
S	1.27	0.229	1, 159	7.14	0.004**	1, 159	7.25	0.004**	1, 159
N	3.02	0.051	1, 159	4.94	0.012**	1, 159	7.36	0.002**	1, 159
H'	11.23	>0.01**	1, 159	0.68	0.423	1, 159	22.31	>0.01**	1, 159
J'	7.56	0.002**	1, 159	5.56	0.011**	1, 159	14.54	>0.01**	1, 159
Δ^+	1.50	0.192	1, 159	6.39	0.007**	1, 159	6.24	0.011**	1, 159
Λ^+	7.79	0.003**	1, 159	7.83	0.003**	1, 159	5.46	0.012**	1, 159
Fish									
S	0.88	0.361	1, 159	6.17	0.007**	1, 159	3.32	0.968	1, 159
N	1.59	0.168	1, 159	6.31	0.002**	1, 159	3.27	0.993	1, 159
H'	1.69	0.190	1, 159	1.37	0.233	1, 159	3.56	0.883	1, 159
J'	2.18	0.065	1, 159	1.17	0.294	1, 159	4.30	0.961	1, 159
Δ^+	1.77	0.267	1, 159	1.63	0.166	1, 159	4.74	0.997	1, 159
Λ^+	0.26	0.893	1, 159	2.20	0.073	1, 159	3.97	0.998	1, 159

RESULTS

We identified 204 species from the collected and observed samples: macroalgae (22 species), molluscs (55), crustaceans (78), echinoderms (11), and fish (38). For macroalgae, the most abundant families were Dictyotaceae (5 species) and Corallinaceae (4 species). Among molluscs, the best represented were Conidae (8 species), Collumbellidae (6 species), and Mytilidae (6 species). Among crustaceans, the best represented were Porcellanidae (12 species), Xanthidae (7 species), and Alpheidae (3 species). Among echinoderms, each of the five families presented two species, and for fishes, the most represented were Labridae (6 species) and Pomacentridae (5 species). Appendix 1 shows all taxa at each site and season.

According to the analysis of species accumulation curves, sampling accounted for over 80 percent of the expected species richness. Based on the Jackknife 1 and Bootstrap tests, the species accumulation curves reached a maximum value of 24 and 23 species for macroalgae; while for molluscs it was 84 and 67; for crustaceans 102 and 89; for echinoderms 12 and 11, and for fish 50 and 46 species.

Results of the PERMANOVA test indicated that the community structure of macroalgae, macroinvertebrates, and fishes tend to be relatively similar between sites (Table 1); and only the molluscs (N) and the echinoderms (H' , J' and Δ^+) showed significant statistical differences (Table 1). Interestingly, for macroalgae and echinoderms the highest S , H' , J' , and Δ^+ occurred at Islas Marietas, while

for the remaining macroinvertebrates (molluscs and crustaceans), all indices were higher at Tehuamixtle (Figs. 2 and 3). Finally, for fish S , N , Δ^+ and Λ^+ were higher at the island (Marietas), while the remaining indices (H' and J') were higher at the coastal site (Table 1, Figs. 2 and 3).

The assemblages of macroalgae, macroinvertebrates, and fishes were different between seasons. For macroalgae, all indices were statistically higher in summer and the same trend was observed for S , Δ^+ and Λ^+ in molluscs. In the case of crustaceans and echinoderms all indices were statistically different between seasons, but higher diversity was registered during the winter. The fish group showed statistical differences only in S and N , with the higher values during the summer (Table 1; Figs. 2 and 3). Finally, the echinoderms were the only group where significant differences in H' and Δ^+ were found between sites and season (Table 1).

The NMDS showed that community structure was relatively homogeneous for each group when comparing sites, as the values dispersion showed no particular pattern. In contrast, all assemblages were different between seasons, except for echinoderms (Fig. 4). According to the SIMPER analysis, the species that contribute the most to the dissimilarity between sites and seasons are the macroalgae *Bossia californica* and *Amphiroa beauvoisii*, the molluscs *Lithophaga aristata* and *Septifer zeteki*, the crustaceans *Acantholobulus mirafloresensis* and *Pimochirus* sp., the echinoderms *Ophiocnida hispida*, *Ophiocoma alexandri*, and *Ophiotrix spiculata*, and the fishes *Halichoeres dispilus*

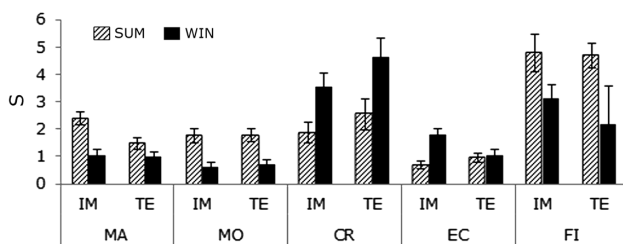
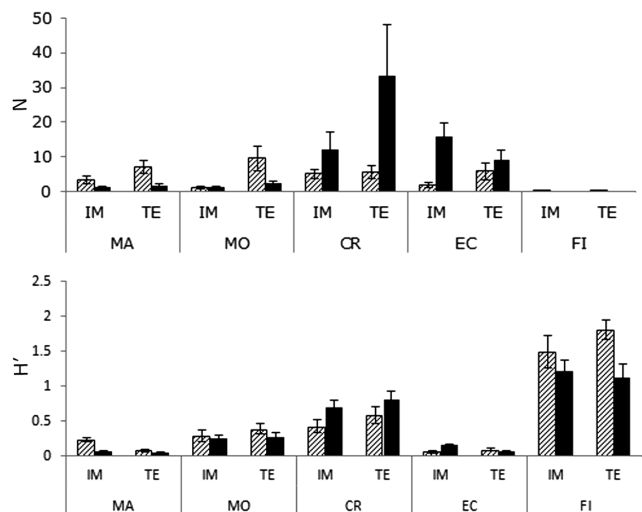


Figure 2. Mean (\pm SE) of species richness (S), relative species abundance (N), and Shannon Index (H') at 2 sites during 2 seasons in the southeastern Gulf of California. IM: Islas Marietas, TE: Tehuamixtle / Promedio (\pm EE) de riqueza de especies (S), abundancia relativa de especies (N) e índice de Shannon (H') en 2 sitios durante 2 estaciones en el sur del Golfo de California. IM: Islas Marietas, TE: Tehuamixtle



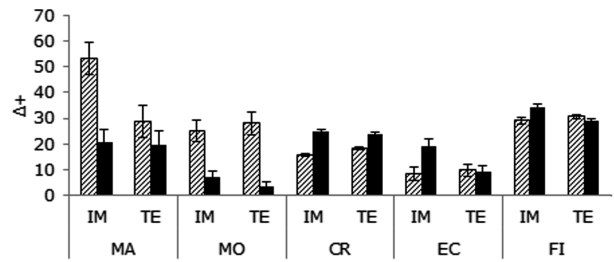
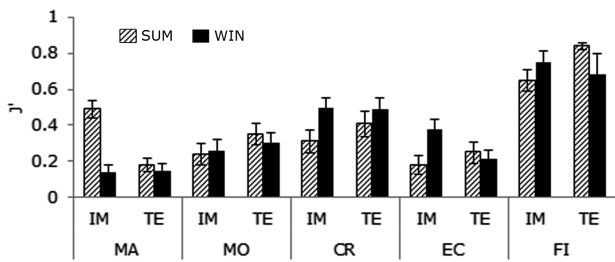


Figure 3. Mean (\pm SE) of Pielou's Index (J), taxonomic distinctness index (Δ^+), and variation in the taxonomic distinctness (Δ^+) at 2 sites during 2 seasons in the southeastern Gulf of California. IM: Islas Marietas, TE: Tehuamixtle / Promedio (\pm EE) del índice de Pielou (J), índice de distintividad taxonómica, (Δ^+), y variación del índice de distintividad taxonómica (Δ^+) en 2 sitios durante 2 estaciones en el sur del Golfo de California. IM: Islas Marietas, TE: Tehuamixtle

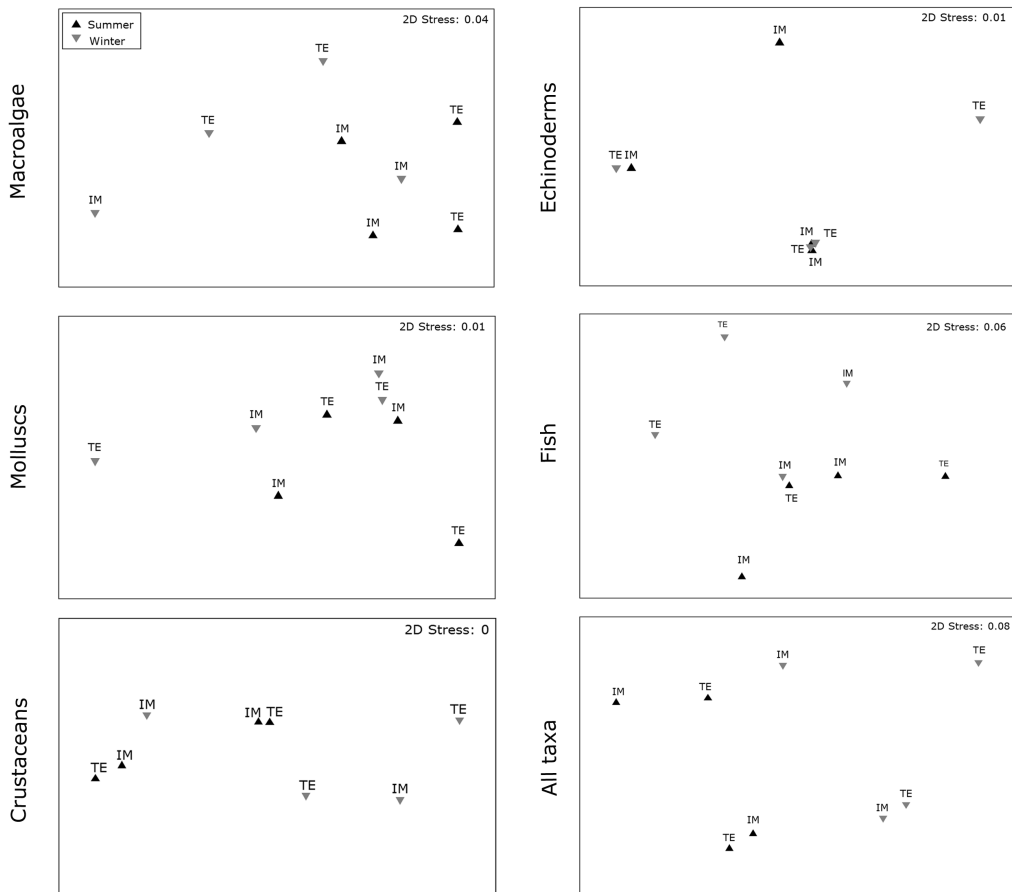
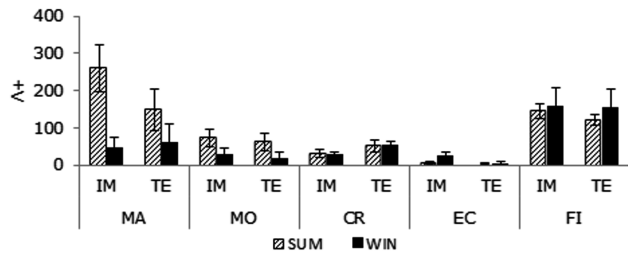


Figure 4. Nonmetric multidimensional scaling plot for taxa at 2 sites and 2 seasons in the southeast of the Gulf of California. IM: Islas Marietas; TE: Tehuamixtle. Black triangles: summer, gray triangles: winter / Escala multidimensional no métrica por taxa en 2 sitios en 2 estaciones en el sur del Golfo de California. IM: Islas Marietas; TE: Tehuamixtle. Triángulos negros: verano, triángulos gris: invierno

and *Thalassoma lucasanum* (Table 2). Together, the NMDS and the dominant species depicted in the SIMPER analyses confirmed that faunal composition between sites is similar (Table 2, Fig. 4).

DISCUSSION

Two general picture emerge from the analysis in this tropical-temperate transitional zone in the Pacific waters off central Mexico. Spatially, there is a high similarity among the assemblages of most taxa in both sites, and on the contrary, a significant seasonal difference in composition and assemblage's descriptor between sites. The overall spatial similarity entails to consider this region as homogeneous from a biological community perspective (Caro *et al.* 2010). This indicates that the environmental factors controlling both areas are similar, that there may be high connectivity among areas, and that they share the regional species pool (Shackell *et al.* 2012). In the

other hand, seasonal differences seem to be a reflex of the recruitment strategies of each taxon. Thus, macroalgae, molluscs and fishes were more diverse in summer, and crustaceans and echinoderms in winter. A similar trend, that is higher diversity during warmer periods, had been reported for algae and fishes for the region (Mateo-Cid & Mendoza-González 1991, 1992; Mendoza-González *et al.* 1994, Aburto-Oropeza & Balart 2001, Alvarez-Filip *et al.* 2007, Galvan-Villa *et al.* 2011, López-Pérez *et al.* 2012,). Reyes-Bonilla and Alvarez-Filip (2008) found the same pattern in reef fishes based on taxonomic distinctness. For molluscs, the differences in richness and taxonomic distinctness between seasons can be due to local recruitment, as suggested by Olabarría *et al.* (2001), since both indices reach higher values in the warm season (spring-summer), when the reproductive peak for most bivalve species in the area occur (Osuna *et al.* 2008).

Table 2. Summary of results from SIMPER tests, showing the relative abundance values for taxa between sites and seasons with the contribution of each taxa to the dissimilarity / Resumen de los resultados del SIMPER, mostrando los valores de abundancia relativa para cada taxa entre sitios y estaciones con la contribución de disimilaridad para cada taxa

Taxa	IM	TE	Av. Diss	Diss (SD)	% Contrib	Cum %	Summer	Winter	Av. Diss	Diss (SD)	% Contrib	Cum %
Macroalgae												
<i>Bossiella californica</i>	0.68	0.75	25.03	0.70	25.93	25.93	1.10	0.33	26.77	0.73	27.58	27.58
<i>Amphiroa beauvoisii</i>	0.19	0.09	6.50	0.34	6.74	32.67	0.18	0.10	5.83	0.34	6.01	33.59
<i>Padina caulescens</i>	0.01	0.39	6.46	0.31	6.70	39.36	–	0.40	5.55	0.29	5.72	39.31
<i>Padina mexicana</i>	0.09	0.11	6.34	0.34	6.57	45.93	0.08	0.12	6.77	0.35	6.97	46.28
<i>Dictyota dichotoma</i> var. <i>intricata</i>	0.11	–	6.12	0.34	6.34	52.27	0.11	–	7.30	0.37	7.52	53.8
TOTAL	1.08	1.34			52.28		1.47	0.83			53.8	
Molluscs												
<i>Lithophaga aristata</i>	0.88	0.74	26.68	0.82	27.82	27.82	0.85	0.76	26.68	0.83	27.70	27.70
<i>Septifer zeteki</i>	0.24	0.33	12.23	0.50	12.75	40.58	0.35	0.21	12.02	0.50	12.48	40.18
<i>Hipponix imbricatus</i>	–	3.04	8.47	0.35	8.84	49.41	3.04	–	8.51	0.34	8.84	49.01
TOTAL	1.12	4.11			49.41		4.24	0.97			49.02	
Crustaceans												
<i>Acantholobulus mirafloresensis</i>	4.05	4.41	17.39	0.67	18.01	18.01	1.39	7.08	15.88	0.64	16.42	16.42
<i>Phimochirus</i> sp.	4.05	3.45	10.66	0.49	11.04	29.04	0.03	7.48	11.93	0.52	12.33	28.75
<i>Pilumnus pygmaeus</i>	0.53	20.81	8.07	0.40	8.35	37.40	0.01	21.33	8.92	0.43	9.22	37.97
<i>Petrolisthes manimaculis</i>	0.29	0.75	6.89	0.47	7.13	44.53	0.21	0.83	7.34	0.47	7.59	52.65
<i>Pisidia magdalenensis</i>	2.10	1.06	5.70	0.42	6.43	50.96	0.11	3.05	6.86	0.43	7.09	52.65
TOTAL	10.49	26.07			50.96		1.75	39.77			52.65	
Echinoderms												
<i>Ophiocnida hispida</i>	6.74	5.56	54.71	1.56	61.14	61.14	1.99	10.31	56.78	1.63	62.54	62.54
TOTAL	6.74	5.56			61.14		1.99	10.31			62.54	
Fish												
<i>Halichoeres dispilus</i>	15.73	5.93	20.22	0.98	24.57	24.57	18.58	5.65	21.14	1.09	25.86	25.86
<i>Thalassoma lucasanum</i>	8.53	4.57	10.92	0.82	13.28	37.85	11.75	3.00	10.68	1.04	13.06	38.92
<i>Stegastes flavilatus</i>	2.93	5.21	7.31	0.92	8.89	46.74	7.25	1.76	7.97	1.12	9.75	48.67
TOTAL	27.19	11.14			46.74		37.58	10.41			48.67	

The cases of crustaceans and echinoderms contrast, in first instance, with the previous reports. Ramírez-Luna *et al.* (2002) and Zamorano & Leyte-Morales (2005) mention that for Huatulco, Mexico, located in the southern part of the Mexican Pacific (16°N), the crustaceans and echinoderms show higher species richness, H' , and abundance during the winter, a pattern that is similar to our results. However, Hernández *et al.* (2009) reported no seasonality in the diversity of reef-associated invertebrates in Bahía de La Paz (24°N). We suggest there is a latitudinal pattern of seasonal change among echinoderms and crustaceans along the coasts of the Mexican Pacific. Future observations toward the south and north may confirm our hypothesis.

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Appendix 1. Abundance of macroalgae (g/0.0625 m²), molluscs, crustaceans, echinoderms (org/0.0625 m²) and fish (fish/10 m²) species in the southern Gulf of California (IM= Islas Marietas, TE= Tehuamixtle) / Abundancia de macroalgas (g 0,0625 m²), moluscos, crustáceos, equinodermos (org/0,0625 m²) y peces (fish/10 m²) en el sur del Golfo de California (IM= Islas Marietas, TE= Tehuamixtle)

Clase/Orden	Family	Specie	Sites		Seasons		
			Im	Te	Summer	Winter	
MACROALGAE							
Ulvophyceae							
Ulvales	Ulvaceae	<i>Ulva californica</i> Wille, 1899	-	<0.010	<0.001	-	
Cladophorales	Cladophoraceae	<i>Chaetomorpha linum</i> (O.F. Müller) Kützinger, 1845	0.003	-	0.003	-	
		<i>Rhizoclonium riparium</i> (Roth) Harvey, 1849	-	0.013	-	0.013	
Bryopsidales	Codiaceae	<i>Codium brandegeei</i> Setchel & N.L. Gardner, 1924	-	<0.01	-	<0.001	
		<i>Codium simulans</i> Setchel & N.L. Gardner, 1924	-	0.008	-	0.009	
	Halimedaceae	<i>Halimeda discoidea</i> Decaisne, 1842	0.017	-	0.002	0.015	
Phaeophyceae							
Dictyotales	Dictyotaceae	<i>Dictyota dichotoma</i> var. <i>intricata</i> (C. Agardh) Greville, 1830	0.111	0.001	0.112	-	
		<i>Padina caulescens</i> Thivy, 1945	0.034	0.084	0.002	0.115	
		<i>Padina crispata</i> Thivy, 1945	0.085	0.111	0.076	0.121	
		<i>Padina durvillei</i> Bory Saint-Vincent, 1827	-	0.576	0.576	-	
		<i>Padina mexicana</i> E.Y. Dawson, 1944	0.041	0.621	0.642	0.019	
Fucales	Sargassaceae	<i>Sargassum liebmannii</i> J. Agardh, 1847	-	1.450	1.450	-	
Florideophyceae							
Gelidiales	Pterocladaceae	<i>Pterocladia capillacea</i> (S.G. Gmelin) Bornet, 1876	0.063	0.059	0.121	-	
Corallinales	Corallinaceae	<i>Amphiroa beauvoisii</i> J.V. Lamouroux, 1816	0.189	0.090	0.176	0.103	
		<i>Bossiella californica</i> (Decaisne) P.C. Silva, 1957	0.682	0.747	1.102	0.327	
		<i>Corallina officinalis</i> var. <i>chilensis</i> (Decaisne) Kützinger, 1858	0.003	0.006	0.003	0.007	
		<i>Jania tenella</i> (Kützinger) Grunow, 1874	0.009	0.388	-	0.398	
Rhodymeniales	Faucheaceae	<i>Gloiocladia conjuncta</i> (Setchel & N.L. Gardner) R.E. Norris, 1991	0.101	-	0.101	-	
	Rhodymeniaceae	<i>Botryocladia pseudodichotoma</i> (Farlow) Kylin, 1931	0.026	-	-	0.026	
		<i>Botryocladia uvarioides</i> E.Y. Dawson, 1944	0.574	-	0.574	-	
	Lomentariaceae	<i>Gelidiopsis tenuis</i> Setchel & N.L. Gardner, 1924	0.425	0.015	0.316	0.124	
Ceramiales	Rhodomeleaceae	<i>Bryothamnion pacificum</i> Taylor, 1945	-	0.324	0.060	0.264	
MOLLUSCS							
Aplacophora			0.013	0.050	0.063	-	
Polyplocophora			0.013	0.013	0.025	-	
Gastropoda							
Archaeogastropoda	Fissurellidae	<i>Fissurella nigrocincta</i> Carpenter, 1856	0.013	-	0.013	-	
Neotaenioglossa	Caliptraeidae	<i>Crucibulum monticulus</i> S.S. Berry, 1969	0.025	0.050	0.075	-	
		<i>Turritella leucostoma</i> Valenciennes, 1832	0.013	-	0.013	-	
	Epitoniidae	<i>Opalia funiculata</i> (Carpenter, 1857)	-	0.013	-	0.013	
	Hipponicidae	<i>Hippinx imbricatus</i> Edmonson, 1933	-	3.038	3.038	-	
	Triviidae	<i>Trivia pacifica</i> (Sowerby, 1832)	0.013	-	-	0.013	
	Cypraeidae	<i>Cypraea albuginosa</i> Gray, 1825	0.013	-	-	0.013	
		<i>Cypraea arabicula</i> Lamarck, 1811	0.038	0.013	0.05	-	
		<i>Cypraea isabellamexicana</i> Stearns, 1893	0.013	-	0.013	-	
	Muricidae	<i>Hexaplex regius</i> (Swainson, 1821)	0.013	-	0.013	-	
		<i>Mancinella speciosa</i> (Valenciennes, 1832)	-	0.050	0.05	-	
		<i>Mancinella triangularis</i> (Blainville, 1832)	-	0.050	0.05	-	
	Buccinidae	<i>Colubraria</i> sp.	0.013	-	-	0.013	
	Columbellidae	<i>Columbella aureomexicana</i> (Howard, 1963)	0.013	-	0.013	-	
		<i>Columbella fuscata</i> Sowerby, 1832	0.013	0.050	0.050	0.013	
		<i>Columbella haemastoma</i> Sowerby, 1832	0.013	-	0.013	-	
<i>Columbella major</i> (Sowerby, 1832)		0.013	-	-	0.013		
<i>Columbella sonsonatensis</i> (Mörch, 1860)		-	0.013	-	0.013		
<i>Columbella</i> sp. (juvenil) Lamarck, 1799		0.050	0.025	0.075	-		
<i>Columbella</i> sp. (juvenil) Lamarck, 1799		0.050	0.025	0.075	-		
Conidae	<i>Conus archon</i> Broderip, 1833	-	0.013	-	0.013		
	<i>Conus gladiator</i> Broderip, 1833	0.063	0.025	0.05	0.038		

Appendix 1. Continued / Continuación

		<i>Conus nux</i> Broderip, 1833	0.075	0.050	0.075	0.05
		<i>Conus purpuracens</i> Sowerby, 1833	-	0.013	-	0.013
		<i>Conus princeps</i> Linnaeus, 1758	0.013	0.013	0.025	-
		<i>Conus tiaratus</i> Sowerby, 1833	-	0.013	-	0.013
		<i>Conus vittatus</i> Hwass, 1792	-	0.013	-	0.013
		<i>Conus ximenes</i> Gray, 1839	-	0.013	-	0.013
	Fascioliariidae	<i>Latirus hemphilli</i> Hertlein & Strong, 1951	-	0.013	0.013	-
		<i>Leucozonia cerata</i> (Wood, 1828)	0.038	0.038	0.075	-
		<i>Opeatostoma pseudodon</i> (Burrow, 1815)	0.013	0.113	0.100	0.025
Neogastropoda	Olividae	<i>Olivella gracilis</i> (Broderip & Sowerby, 1828)	0.013	-	-	0.013
	Marginellidae	<i>Volvarina taeniolata</i> Morch, 1860	0.013	-	0.013	-
	Cystiscidae	<i>Persicula phrygia</i> (Sowerby, 1846)	0.038	0.025	0.05	0.013
	Mitridae	<i>Mitra tristis</i> Broderip, 1836	0.013	-	0.013	-
Cephalaspidea	Bullidae	<i>Bulla gouldiana</i> Pilsbry, 1895	0.013	-	0.013	-
Bivalvia						
Arcoidea	Arcidae	<i>Acar gradata</i> (Broderip & Sowerby, 1829)	0.013	-	0.013	-
	Arcidae		0.013	0.038	0.05	-
	Glycymerididae	<i>Glycymeris multicostrata</i> (Sowerby, 1833)	0.013	0.013	0.025	-
Mytiloidea	Mytilidae	<i>Lithophaga aristata</i> (Dillwyn, 1817)	0.875	0.738	0.850	0.763
		<i>Lithophaga plumula</i> (Hanley, 1843)	0.013	-	-	0.013
		<i>Modiolus capax</i> (Conrad, 1837)	0.050	0.288	0.338	-
		<i>Mytella guyanensis</i> (Lamarck, 1819)	0.038	0.050	0.075	0.013
		<i>Mytella strigata</i> (Hanley, 1843)	0.013	0.013	0.013	0.013
		<i>Septifer zeteki</i> Hertlein & Strong, 1946	0.238	0.325	0.350	0.213
Pterioidea	Pteriidae	<i>Pinctada mazatlanica</i> (Hanley, 1856)	0.025	-	-	0.025
Limoida	Limidae	<i>Lima tetrica</i> Gould, 1851	0.013	-	0.013	-
Veneroidea	Carditidae	<i>Cardites grayi</i> Dall, 1903	0.050	-	0.038	0.013
	Veneridae	<i>Chione</i> sp.	-	0.013	0.013	-
	Psammobiidae	<i>Gari regularis</i> (Carpenter, 1864)	0.013	-	0.013	-
	Semelidae	<i>Abra tepocana</i> Dall, 1915	0.013	-	0.013	-
	Cardiidae	<i>Trachycardium pristipleura</i> (Dall, 1901)	0.013	-	0.013	-
	Cardiidae		-	0.013	0.013	-
Pholadomyoidea	Pandoridae		0.038	0.050	0.088	-
CRUSTACEANS						
Malacostraca						
Amphipoda	Ampithoidae		0.025	-	-	0.025
	Anamixidae		-	0.038	0.038	-
	Caprellidae		0.025	0.063	0.075	0.013
	Gammaridae		0.025	0.025	0.025	0.025
	Lysianassidae		-	0.05	0.025	0.025
	Megaluropidae		0.075	0.013	0.013	0.075
	Melitidae		0.500	0.613	0.663	0.45
	Philantidae	<i>Pariphinotus scabrosus</i> (J. L. Barnard, 1969)	-	0.013	-	0.013
	Podoceridae		-	0.013	-	0.013
Decapoda	Acidopsidae	<i>Acidops fimbriatus</i> Stimpson, 1871	-	0.05	0.025	0.025
	Alpheidae	<i>Alpheus cf. websteri</i> Kingsley, 1880	0.250	0.888	0.575	0.563
		<i>Alpheus malleator</i> Dana, 1852	-	0.038	-	0.038
		<i>Alpheus</i> sp.	0.088	0.188	0.088	0.188
	Dairidae	<i>Daira americana</i> Stimpson, 1860	-	0.025	0.025	-
	Diogenidae	<i>Calcinus californiensis</i> Bouvier, 1898	0.050	0.050	0.088	0.013
		<i>Clibanarius lineatus</i> (Milne, 1848)	-	0.038	-	0.038
		<i>Paguristes</i> sp.	0.038	-	0.038	-
		<i>Trizopagurus magnificus</i> (Bouvier, 1898)	-	0.075	-	0.075

Appendix 1. Continued / Continuación

	Epialtidae	<i>Acanthonyx petiverii</i> H. Milne Edwards, 1834	0.013	0.175	0.013	0.175
		<i>Epialtoides paradigmus</i> Garth, 1958	-	0.013	-	0.013
		<i>Epialtus minimus</i> Lockington, 1877	0.038	-	0.025	0.013
		<i>Pitho sexdentata</i> Bell, 1835	0.050	0.675	0.100	0.625
	Inachidae	<i>Eucinetops rubellatus</i> Rathbun, 1923	-	0.013	0.013	-
		<i>Ericerodes casooe</i> Hendricks, 1987	0.150	0.225	0.100	0.275
		<i>Ericerodes veleronis</i> Garth, 1948	-	0.125	-	0.125
		<i>Stenorhynchus debilis</i> Smith, 1871	0.413	0.138	-	0.55
		<i>Inachoides laevis</i> Stimpson, 1860	0.025	0.025	-	0.05
	Majidae	<i>Microphrys platysoma</i> (Stimpson, 1860)	-	0.013	-	0.013
		<i>Mithrax pygmaeus</i> Bell, 1835	-	0.013	-	0.013
		<i>Teleophrys cristulipes</i> Stimpson, 1860	0.038	-	0.038	-
	Oziidae	<i>Eupilumnus xantusii</i> Stimpson, 1860	-	0.138	0.025	0.113
	Paguridae	<i>Phimochirus</i> sp.	4.05	3.450	0.025	7.475
	Palaemonidae	<i>Brachycarpus biunguiculatus</i> (Lucas, 1846)	-	0.013	0.013	-
		<i>Pontonia margarita</i> (Smith, 1869)	0.013	0.013	-	0.025
	Panopeidae	<i>Acantholobulus mirafloresensis</i> (Abele & Kim, 1989)	4.050	4.413	1.388	7.075
		<i>Lophoxanthus lamellipes</i> (Stimpson, 1860)	0.025	0.038	0.050	0.013
	Parthenopidae	<i>Ochtholambrus stimpsoni</i> (Garth, 1958)	0.188	0.738	0.325	0.6
		<i>Parthenope</i> sp.	0.088	0.100	0.100	0.088
		<i>Solenolambrus arcuatus</i> Stimpson, 1871	-	0.025	-	0.025
	Pilumnidae	<i>Pilumnus pygmaeus</i> Boone, 1927	0.525	20.813	0.013	21.325
		<i>Pilumnus stimpsonii</i> Miers, 1886	-	0.013	-	0.013
	Pinnotheridae	<i>Calyptrea theresgranti</i> (Glassell, 1933)	0.063	-	0.050	0.013
	Porcellanidae	<i>Clastoecochus diffractus</i> (Haig, 1957)	-	0.013	0.013	-
		<i>Neopisosoma dohenyi</i> Haig, 1960	0.013	-	-	0.013
		<i>Orthochela pumila</i> Glassell, 1936	-	0.213	0.088	0.125
		<i>Pachycheles biocellatus</i> (Lockington, 1878)	-	0.063	0.050	0.013
		<i>Pachycheles spinidactylus</i> Haig, 1957	-	0.013	-	0.013
		<i>Petrolisthes edwardsii</i> (De Saussure, 1853)	-	0.025	-	0.025
		<i>Petrolisthes haigae</i> Chace, 1962	-	0.013	-	0.013
		<i>Petrolisthes hians</i> Nobili, 1901	0.013	0.025	0.025	0.013
		<i>Petrolisthes manimaculis</i> Glassell, 1945	0.288	0.750	0.213	0.825
		<i>Petrolisthes polymitus</i> Glassell, 1937	0.038	-	0.025	0.013
		<i>Petrolisthes sanfelipensis</i> Glassell, 1936	0.200	-	-	0.200
		<i>Pisidia magdalenensis</i> (Glassell, 1936)	2.100	1.063	0.113	3.050
	Trapeziidae	<i>Trapezia bidentata</i> (Forskål, 1775)	0.013	-	0.013	-
	Xanthidae	<i>Heteractaea lunata</i> (Lucas, 1844)	-	0.025	0.013	0.013
		<i>Lipaesthesius leeanus</i> Rathbun, 1898	-	0.025	0.025	-
		<i>Medaesus spinulifer</i> (Rathbun, 1898)	0.013	0.025	0.013	0.025
		<i>Paractaea sulcata</i> Stimpson, 1860	0.025	0.013	0.013	0.025
		<i>Platyodiella rotundata</i> Stimpson, 1860	-	0.100	-	0.100
		<i>Xanthodius stimpsoni</i> (A. Milne-Edwards, 1879)	0.025	-	-	0.025
	Xanthidae		0.925	0.225	0.125	1.025
Isopoda	Anthuridae	Anthuridae sp. 1	0.025	-	0.025	-
		Anthuridae sp. 2	-	0.025	0.025	-
		Anthuridae sp. 3	-	0.013	0.013	-
	Cirolanidae	Cirolanidae sp. 1	-	0.013	0.013	-
Cirolanidae sp. 2		0.125	0.025	0.138	0.013	
Cirolanidae sp. 3		0.063	0.038	0.025	0.075	
Cirolanidae sp. 4		0.013	0.063	0.038	0.038	
Idoteidae		-	0.063	0.013	0.05	
Sphaeromatidae	<i>Paracerceis sculpta</i> (Holmes, 1904)	-	0.025	-	0.025	

Appendix 1. Continued / Continuación

Mysida	Mysidae	<i>Mysida</i> sp.	-	0.013	-	0.013
Stomatopoda	Gonodactyloidea	<i>Neogonodactylus stanchi</i> (Schmitt, 1940)	-	0.013	-	0.013
Tanaidacea	Tanaidacea		-	0.013	-	0.013
Maxillopoda						
Sessilia	Balanidae	<i>Balanus</i> sp. 1	-	0.063	0.063	-
		<i>Balanus</i> sp. 2	-	0.338	0.300	0.038
		<i>Balanus</i> sp. 3	0.013	0.013	0.013	0.013
		<i>Megabalanus</i> sp.	0.050	0.088	0.063	0.075
ECHINODERMS						
Echinoidea						
Cidaroida	Cidariidae	<i>Eucidaris thouarsii</i> (Valenciennes, 1846)	0.113	0.013	0.075	0.050
Ophiuroidea						
Ophiurida	Ophiocomidae	<i>Ophiocoma aethiops</i> Lütken, 1859	0.088	0.038	0.063	0.063
		<i>Ophiocoma alexandri</i> Lyman, 1860	0.713	0.275	0.225	0.763
	Ophionereididae	<i>Ophionereis annulata</i> (Le Conte, 1851)	0.013	-	-	0.013
		<i>Ophionereis perplexa</i> Ziesenhenné, 1940	0.063	0.013	0.038	0.038
	Ophiactidae	<i>Ophiactis savignyi</i> (Müller & Troschel, 1842)	-	0.050	0.038	0.013
		<i>Ophiactis simplex</i> (Le Conte, 1851)	0.100	0.113	0.088	0.125
	Amphiuridae	<i>Amphipholis squamata</i> (Delle Chiaje, 1828)	0.013	-	-	0.013
		<i>Ophiocnida hispida</i> (Le Conte, 1851)	6.738	5.568	1.988	10.318
	Ophiotrichidae	<i>Ophiothela mirabilis</i> Verrill, 1867	0.525	0.875	1.188	0.213
		<i>Ophiotrix spiculata</i> Le Conte, 1851	0.600	0.684	0.247	1.038
FISH						
Chondrichthyes						
Myliobatiformes	Urotrygonidae	<i>Urobatis concentricus</i> Osburn & Nichols, 1916	0.025	0.011	-	0.036
	Dasyatidae	<i>Dasyatis dipterura</i> (Jordan & Gilbert, 1880)	-	0.006	-	0.006
Actinopterygii						
Anguilliformes	Muraenidae	<i>Echidna nebulosa</i> (Ahl, 1789)	0.006	-	-	0.006
		<i>Echidna nocturna</i> (Cope, 1872)	0.013	-	0.006	0.006
		<i>Gymnothorax castaneus</i> (Jordan & Gilbert, 1883)	0.006	-	-	0.006
Beryciformes	Holocentridae	<i>Myripristis leiognathus</i> Valenciennes, 1846	-	0.138	-	0.138
Perciformes	Serranidae	<i>Cephalopholis panamensis</i> (Steindachner, 1876)	0.013	-	0.013	-
		<i>Epinephelus labriformis</i> (Jenyns, 1840)	0.238	0.305	0.406	0.136
		<i>Serranus psittacinus</i> Valenciennes, 1846	0.056	-	-	0.056
	Carangidae	<i>Caranx sexfasciatus</i> Quoy & Gaimard, 1825	-	0.033	0.033	-
		<i>Gnathanodon speciosus</i> (Forsskål, 1775)	-	0.008	0.008	-
	Lutjanidae	<i>Lutjanus viridis</i> (Valenciennes, 1846)	-	0.513	0.513	-
	Haemulidae	<i>Haemulon flaviguttatum</i> Gill, 1862	-	0.148	0.058	0.09
	Sciaenidae	<i>Pareques cf. viola</i> (Gilbert, 1898)	-	0.025	-	0.025
	Mullidae	<i>Mulloidichthys dentatus</i> Gill, 1862	-	0.075	0.075	-
	Chaetodontidae	<i>Chaetodon humeralis</i> Günther, 1860	0.248	0.114	0.146	0.216
		<i>Johnrandallia nigrirostris</i> (Gill, 1862)	0.065	0.167	0.188	0.044
	Pomacanthidae	<i>Holacanthus passer</i> Valenciennes, 1846	0.027	0.005	0.015	0.018
		<i>Pomacanthus zonipectus</i> (Gill, 1863)	0.013	-	-	0.013
	Cirrhitidae	<i>Cirrhitus rivulatus</i> Valenciennes, 1846	-	0.005	-	0.005
	Pomacentridae	<i>Abudefduf troschelii</i> (Gill, 1862)	-	0.042	0.042	-
		<i>Chromis atrilobata</i> Gill, 1862	0.565	0.106	0.565	0.106
		<i>Microspathodon dorsalis</i> (Gill, 1862)	0.044	0.100	0.115	0.029
		<i>Stegastes flavilatus</i> (Gill, 1862)	0.308	0.64	0.771	0.178
		<i>Stegastes rectifraenum</i> (Gill, 1862)	0.135	0.110	0.188	0.058

Appendix 1. Continued / Continuación

Tetraodontiformes	Labridae	<i>Bodianus diplotaenia</i> (Gill, 1862)	0.129	0.288	0.373	0.044
		<i>Halichoeres chierchiae</i> Di Caporiacco, 1948	0.308	0.015	0.31	0.013
		<i>Halichoeres dispilus</i> (Günther, 1864)	1.617	0.823	1.856	0.584
		<i>Halichoeres nicholsi</i> (Jordan & Gilbert, 1882)	0.048	-	0.035	0.013
		<i>Halichoeres notospilus</i> (Günther, 1864)	0.158	0.092	0.206	0.044
		<i>Thalassoma lucasanum</i> (Gill, 1862)	0.873	0.754	1.308	0.319
	Blenniidae	<i>Ophioblennius steindachneri</i> Jordan & Evermann, 1898	0.021	0.025	0.04	0.006
	Acanthuridae	<i>Acanthurus nigricans</i> (Linnaeus, 1758)	0.006	-	0.006	-
	Balistidae	<i>Balistes polylepis</i> Steindachner 1876	-	0.008	0.008	-
	Tetraodontidae	<i>Arothron meleagris</i> (Lacepède, 1798)	0.019	0.005	-	0.024
		<i>Canthigaster punctatissima</i> (Günther, 1870)	0.006	0.008	0.015	-
		<i>Sphoeroides lobatus</i> (Steindachner, 1870)	0.006	-	0.006	-
	Diodontidae	<i>Diodon holocanthus</i> Linnaeus, 1758	-	0.053	0.013	0.04