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ARTICLE

Changes in fish community structures in a coastal lagoon in the Gulf of California, México

Variaciones en la estructura comunitaria de peces en una laguna costera del Golfo de California, México

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Resumen.- Las lagunas costeras se caracterizan por su alta diversidad, riqueza y abundancia de peces, las cuales pueden ser modificadas por la variabilidad de las condiciones ambientales. El presente estudio tiene como objetivo describir la estructura de la comunidad de peces y relacionar su variabilidad estacional con los parámetros de temperatura y salinidad en una laguna costera. Durante 6 campañas de muestreo se recolectaron 4.199 peces, agrupados en 95 especies. Los resultados indicaron que la riqueza, diversidad y equidad tuvieron un comportamiento estacional similar con valores mayores durante otoño 2010, primavera 2011 y 2012; la abundancia fue mayor en otoño 2010, verano 2011 y 2012 y la biomasa en otoño 2010 y verano 2011. La relación de la temperatura y salinidad a través del análisis RDA con los parámetros ecológicos, indicó que algunas de las especies dominantes son de afinidad cálida y otras de afinidad fría. Mientras que la riqueza y diversidad se incrementan durante temporadas frías, la biomasa y equidad aumentan en las temporadas de mayor salinidad; por su parte la abundancia se incrementa en temporadas cálidas. Las curvas ABC mostraron estrés moderado durante invierno y verano de 2012 y el MDS indicó la formación de 4 grupos, dos integrados por 2 periodos de muestreo y dos por uno solo de ellos. Los parámetros ecológicos presentaron variaciones estacionales debido a la influencia de los cambios en temperatura y salinidad.

Palabras clave: Variabilidad estacional, parámetros ecológicos, comunidad de peces, laguna costera

Abstract.- Coastal lagoons are characterized by high diversity, richness, and abundance of fishes, which can be modified by high variability of environmental conditions. The present study aims to describe the structure of the fish community and related its seasonal variability with temperature and salinity in a coastal lagoon. During 6 seasonal sampling campaigns 4,199 fish were collected and grouped in 95 species. The results indicated that richness, diversity and evenness indices showed similar pattern with higher values in autumn 2010, spring 2011 and 2012, abundance was higher in autumn 2010, summer 2011 and 2012 and biomass in autumn 2010 and summer 2011. Relationship of temperature and salinity through the RDA analysis with ecological parameters indicated that some dominant species are of warm affinity and other of cold affinity. Richness and diversity increase during cold seasons, while biomass and evenness increase in seasons of higher salinity and abundance increases in warm seasons. The ABC curves showed moderate stress in winter and summer 2012 and MDS indicate the formation of 4 groups, two integrated by 2 sampling periods and two by single sampling period. Ecological parameters showed seasonal variations because they are influenced by changes of temperature and salinity.

Key words: Seasonal variability, ecological parameters, fish community, coastal lagoon

INTRODUCTION

Coastal lagoons are ecosystems characterized by having a complex ecological structure related with habitat heterogeneity, high biological diversity, and important primary productivity (Díaz *et al*. 2004, Rodríguez *et al*. 2011). In these environments, different groups of organisms are found, such as fish that have penetrated this area in a certain stage of their life cycle, where hydrological conditions vary considerably (Castro *et al.* 1999).

At world level fish are known as organisms that use these spaces for reproduction, feeding, and self-protection in early stages of their life cycle (Kuo *et al.* 2001, Tsai *et al.* 2015). Abundance, composition and diversity of this group have been well examined in different lagoons with estuarine characteristics in different parts of the world (Akin *et al.* 2005, França *et al.* 2009, Castillo *et al*. 2010).

Indices of abundance, biomass, richness, and diversity show changes that are attributed to variability of the environmental conditions that occur in coastal lagoons (Hagan & Able 2008, Vasconcelos *et al*. 2010). Salinity, temperature, turbidity, depth, and vegetation are within the factors affecting fish community structure (Huxham *et al*. 2004, Tsai *et al*. 2015).

Anti-estuary lagoons are found in the Gulf of California (GC) where salinities are higher than those in the ocean, and studies of composition, abundance, distribution, and diversity of the fish that inhabit them have conducted (Findley & Thomson 1973, Yépiz 1990, Núñez 1991, Grijalva *et al*. 1992, Aguirre 1995, Grijalva *et al*. 1996).

In Las Guásimas lagoon, exist studies on the variation of community structure (Yépiz 1990, Rodríguez 2010, Ontiveros 2011), however information was obtained from data collected more than 25 years ago, in which the lagoon has been object of innumerable changes due to human settlements on its margins and the same climate that has possibly changed because of the global warming (Padilla *et al*. 2016). In this context the general objective of this study was to describe the community structure, with emphasis on its seasonal variation and its relationship with temperature and salinity.

Materials and methods

Study area

The coastal lagoon Las Guásimas is an ecosystem within the Ramsar sites. It is located in northwestern Mexico within the GC in the coastal plains of the state of Sonora, from 27°49' and 27°55'N to 110°29' and 110°40'W. It has an extension of 4.076 ha together with its two estuaries (Bachoco and Mápoli) with an average depth of 0.7 m, and its bottom is formed mainly by sand and clay. The limiting zone has mangrove scarce in abundance and height; the only source of fresh water comes from precipitation occurring during summer (García 1988) (Fig. 1).

Sampling

Fish sampling was performed during 6 periods: November 2010 (autumn), May 2011 (spring), September 2011 (summer), February 2012 (winter), May 2012 (spring), and August 2012 (summer). With the objective of obtaining the highest number of fish in the area, collection of organisms was performed on board a small vessel using 3 types of fishing gear, line dragnet, casting net and trawling net. Samplings were performed in the internal part and mouth of the lagoon. Because the lagoon is shallow making it difficult to access much of its area, the sampling points were defined by the possibility of fishing gear access (Fig. 1). For this reason, a defined station grid was not followed, taking care in considering the information within and out of the lagoon. The total fish sampling was collected and placed in bags duly tagged for subsequent analyses. Surface sea water temperature and salinity were recorded using YSI multi-parameter equipment (YSI, Inc., Yellow Springs, OH, U.S.A.).

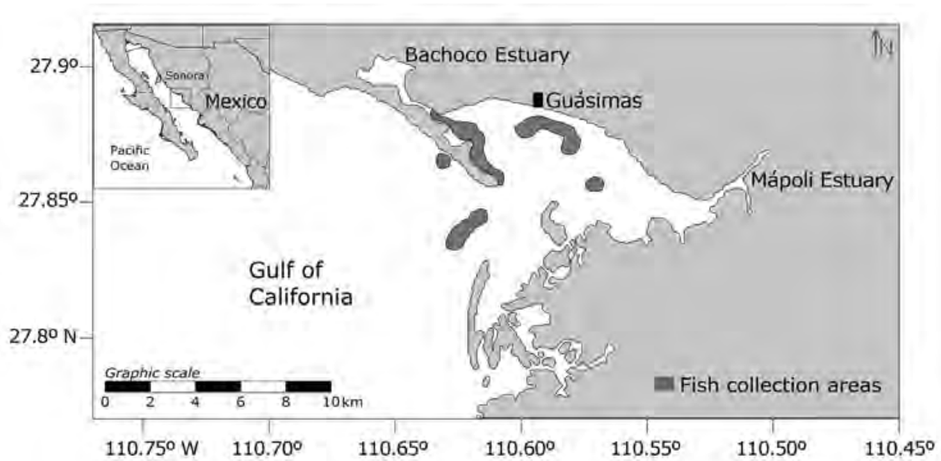

Figure 1. Study area and location of collection areas of fish fauna in the coastal lagoon Las Guásimas Sonora, México / Área de estudio y ubicación de las zonas de colecta de la fauna de peces en la laguna costera Las Guásimas Sonora, México

Laboratory activities

The taxonomic identification of species was performed according to the descriptions and keys of Jordan & Evermann (1896-1900), Meek & Hildebrand (1923-1928), Miller & Lea (1976), Eschmeyer *et al*. (1983), Fischer *et al*. (1995a, b), Castro *et al*. (1999), and Robertson & Allen (2015), systematic list of species was performed according to Nelson (2006). The organisms of each species were counted and weighed (g) individually. The species were classified according to their life history based on frequency of occurrence (FO) obtaining 3 categories (Stoner 1986): (1) resident species (RE) (61-100% de FO); (2) temporary, seasonal, or cyclical visitors (CV) (31-60% de FO), and (3) occasional visitors (OV) (0-30% de FO).

Data analysis

To evaluate seasonal differences of environmental variables a one-way analysis of variance (ANOVA) was performed and a Tukey test was applied, and the measurements of the variables were compared to determine which climate seasons showed no differences. The ecological parameters used to describe the community were: species richness (S), diversity of Shannon (*H'*) and evenness (*E*), which were determined using the program PRIMER (Clarke & Gorley 2001). Because the collection of organisms was performed with different fishing gear and different effort, and with the purpose of comparing them, abundance and biomass were standardized to individuals and grams (g) per m^{-2} to avoid bias in capture effort; this standardization was performed through the swept area method.

Dominance was determined using the Biological Index Value (BIV), because this method balances the temporal-spatial trend in species abundance by assigning points in terms of numerical abundance to each sample to avoid ordering species based on accurate dominant data but with little representativeness (Loya & Escofet 1990). To evaluate the potential relationship between dominant species abundance and temperature and salinity, the redundancy analysis (RDA) was used. This same procedure was used to search for the relationship of the environmental variables and ecological parameters (abundance biomass, species richness, diversity, and evenness) these calculi were performed with the software CANOCO 4.5 (NY, USA).

The abundance-biomass curves (ABC) were compared to determine whether ecosystem stress was found in each climate season, and statistical *W* was used. To determine differences in fish assemblage structure, the similarity matrix was used based on the Bray-Curtis coefficient with the seasonal abundances transformed to log (X+1). Ordering was performed with non-metric multidimensional scaling (MDS). The analysis of similarity (ANOSIM) was performed to show differences among the groups formed in the MDS. With the similarity percentage (SIMPER) analysis, the responsible species in the grouping pattern were defined. These multivariate analyses were performed with the PRIMER (Clarke & Gorley 2001).

Results

Environmental variability

Las Guásimas lagoon showed a seasonal temperature pattern, where an average value of 26.05 ± 1.7°C was observed with higher record during the summer 2011 (September) with 33.05°C and a minimum average in the winter 2012 (February) with 17.5°C. Salinity also showed a seasonal trend (Table 1) with an mean value of 37.8 ± 0.9, the greatest record was observed in the spring 2011 (May) with 42.3 and the minimum in the winter 2012 (February) with 34.7. The ANOVA for both variables showed significant differences among some seasons of the year (temperature $FC_{621.74} > F_{0.05,\, 2.47}$; salinity $FC_{47.5} > F_{0.05,\, 2.49}$). The Tukey test showed that temperature was not significantly different between the autumn 2010 and spring 2011. As for salinity, no significant differences were found between the autumn 2010 and spring 2012: the spring and summer 2011; the winter and summer 2012.

Species composition, abundance, and biomass

In total, 4,199 fish were collected with a weight of 171.5 kg during the 6 sampling campaigns. 38 families, 67 genera, and 95 species composed the community (Table 2). The families with the highest number of species were Carangidae (12), Sciaenidae (10), Haemulidae (8), Paralichthydae (7), Engraulidae (5), and Gerreidae (5). Fifty-eight species accumulated <10% of total abundance during the 6 seasons.

Table 1. Mean temperature and salinity per sampling period / Promedio de temperatura y salinidad por periodo de muestreo

Seasons	Temperature (°C)	SD±	Salinity	SD±
Autumn 2010	22.3	0.2	37.7	0.3
Spring 2011	21.1	1.5	42.3	0.9
Summer 2011	33.1	0.3	42.0	1.0
Winter 2012	17.6	0.5	34.7	0.4
Spring 2012	26.5	0.5	37.6	2.0
Summer 2012	32.0	0.5	35.6	0.6

Table 2. Numerical composition of the fish species captured in the 6 climate seasons in the lagoon Las Guásimas; (N%) relative abundance; (B%) relative biomass; (FO%) relative frequency of occurrence. Classification by life history (RE= resident species; CE= cyclical or seasonal especies; OV= occasional visitors). The range is based on the relative abundance of each one species, while the dominance represents the species with the highest biological index value (BIV) / Composición numérica de las especies de peces capturadas en las 6 estaciones climáticas en la laguna Las Guásimas; (N%) abundancia relativa; (B%) biomasa relativa; (FO%) frecuencia relativa de ocurrencia. Clasificación por historia de vida (RE= especies residentes; CE= estacionales o cíclicas y OV= ocasionales). El rango está basado en la abundancia relativa de cada una de las especies, mientras que la dominancia representa a las especies con mayor índice de valor biológico (IVB)

Family/Species	Rank	N%	B%	FO%	Life history	Dominant species
CARCHARHINIDAE						
Carcharhinus cerdale Gilbert, 1898	42	0.36	2.62	33.3	CE	
UROLOPHIDAE						
Urolophus halleri Cooper, 1863	25	0.91	1.48	50	CE	
Urolophus maculatus (Garman, 1913)	45	0.26	0.66	33.3	CE	
GYMNURIDAE						
Gymnura marmorata (Cooper, 1864)	62	0.02	2.00	16.7	OV	
RHINOPTERIDAE						
Rhinoptera steindachneri Evermann & Jenkins, 1891	63	0.01	2.13	16.7	OV	
ELOPIDAE						
Elops affinis Regan, 1909	63	0.01	0.04	16.7	OV	
ALBULIDAE						
Albula esuncula (Garman, 1899)	31	0.62	1.14	50	CE	
CONGRIDAE						
Ariosoma gilberti (Ogilby, 1898)	61	0.03	0.03	33.3	CE	
OPHICHTHIDAE						
Ophichthus zophochir Jordan & Gilbert, 1882	46	0.25	0.51	50	CE	
ENGRAULIDAE						
Anchoa ischana (Jordan & Gilbert, 1882)	21	1.15	0.20	50	CE	
Anchoa lucida (Jordan & Gilbert, 1882)	34	0.53	0.11	33.3	CE	
Anchoa nasus (Kner & Steindachner, 1867)	17	1.52	0.30	66.7	RE	X
Anchovia macrolepidota (Kner, 1863)	5	4.11	1.23	100	RE	X
Cetengraulis mysticetus (Günther, 1867)	12	2.33	1.38	33.3	CE	X
CLUPEIDAE						
Harengula thrissina (Jordan & Gilbert, 1882)	39	0.42	0.12	33.3	CE	
Lile stolifera (Jordan & Gilbert, 1882)	55	0.09	0.03	16.7	OV	
Opisthonema libertate (Günther, 1867)	40	0.39	0.72	33.3	CE	
ARIIDAE						
Ariopsis seemanni (Günther, 1864)	23	1.06	2.17	50	CE	X
Ariopsis sp.	22	1.10	1.98	16.7	OV	
Occidentarius platypogon (Günther, 1864)	58	0.06	0.22	16.7	OV	
SYNODONTIDAE						
Synodus lucioceps (Ayres, 1855)	56	0.08	0.21	33.3	CE	
Synodus scituliceps Jordan & Gilbert, 1882	42	0.36	0.26	66.7	RE	
BATRACHOIDIDAE						
Porichthys analis Hubbs & Schultz, 1939	63	0.01	0.02	16.7	OV	
Porichthys notatus Girard, 1854	62	0.02	0.00	16.7	OV	
MUGILIDAE						
Mugil cephalus Linnaeus, 1758	44	0.28	0.34	50	CE	
Mugil curema Valenciennes, 1836	29	0.74	0.92	33.3	CE	
ATHERINOPSIDAE						
Atherionops affinis (Ayres, 1860)	38	0.43	0.14	33.3	CE	
Leuresthes sardina (Jenkins & Evermann, 1889)	4	6.38	4.07	66.7	RE	X
BELONIDAE						
Strongylura exilis (Girard, 1854)	59	0.05	0.30	16.7	OV	
SCORPAENIDAE						
Scorpaena sonorae Jenkins & Evermann, 1889	50	0.16	0.01	50	CE	
CENTROPOMIDAE						
Centropomus robalito Jordan & Gilbert, 1882	58	0.06	0.12	16.7	OV	
SERRANIDAE						
Diplectrum pacificum Meek & Hildebrand, 1925	35	0.51	0.37	66.7	RE	
Paralabrax maculatofasciatus (Steindachner, 1868)	10	2.87	3.87	100	RE	X
NEMATISTIIDAE						
Nematistius pectoralis Gill, 1862	14	1.84	6.01	33.3	CE	
CARANGIDAE						

Table 2. Continued / Continuación

Family/Species	Rank	N%	B%	FO%	Life history	Dominant species
Carangoides otrynter Jordan & Gilbert, 1883	53	0.12	0.19	16.7	OV	
Caranx caballus Günther, 1868	11	2.49	11.36	33.3	CE	
Caranx caninus Günther, 1867	41	0.37	0.60	33.3	CE	
Caranx vinctus Jordan & Gilbert, 1882	15	1.83	2.78	33.3	CE	
Chloroscombrus orqueta Jordan & Gilbert, 1883	18	1.30	1.43	16.7	OV	
Oligoplites altus (Günther, 1868)	57	0.07	0.27	33.3	CE	
Oligoplites refulgens Gilbert & Starks, 1904	58	0.06	0.02	16.7	OV	
Oligoplites saurus (Bloch & Schneider, 1801)	47	0.24	0.21	16.7	OV	
Selene brevortii (Gill, 1863)	45	0.26	0.06	33.3	CE	
Selene peruviana (Guichenot, 1866)	43	0.29	0.05	33.3	CE	
Trachinotus kennedyi Steindachner, 1876	49	0.18	1.29	16.7	OV	
Trachinotus rhodopus Gill, 1863	58	0.06	0.07	16.7	OV	
LUTJANIDAE						
Hoplopagrus guentherii Gill, 1862	53	0.12	0.08	16.7	OV	
Lutjanus argentiventris (Peters, 1869)	58	0.06	0.01	16.7	OV	
GERREIDAE						
Diapterus brevirostris (Sauvage, 1879)	1	16.61	2.77	50	CE	
Eucinostomus currani Zahuranec, 1980	31	0.62	0.16	50	CE	
Eucinostomus dowii (Gill, 1863)	6	3.77	0.65	66.7	RE	X
Eucinostomus entomelas Zahuranec, 1980	3	7.94	8.33	83.3	RE	X
Eugerres axillaris (Günther, 1864)	8	3.06	0.60	50	CE	X
HAEMULIDAE						
Haemulon maculicauda (Gill, 1862)	62	0.02	0.00	16.7	OV	
Haemulon sexfasciatum Gill, 1862	26	0.85	0.15	33.3	CE	
Haemulopsis elongatus (Steindachner, 1879)	37	0.44	0.59	50	CE	
Haemulopsis nitidus (Steindachner, 1869)	33	0.55	0.25	50	CE	
Orthopristis reddingi Jordan & Richardson, 1895	56	0.08	0.04	33.3	CE	
Pomadasys branickii (Steindachner, 1879)	33	0.55	0.13	33.3	CE	
Pomadasys macracanthus (Günther, 1864)	40	0.39	0.48	33.3	CE	
Pomadasys panamensis (Steindachner, 1876)	59	0.05	0.06	16.7	OV	
POLYNEMIDAE						
Polydactylus approximans (Lay & Bennett, 1839)	36	0.45	0.43	33.3	CE	
SCIAENIDAE						
Bairdiella icistia (Jordan & Gilbert, 1882)	28	0.75	0.47	50	CE	
Cheilotrema saturnum (Girard, 1858)	52	0.14	0.13	16.7	OV	
Cynoscion parvipinnis Ayres, 1861	35	0.51	1.05	50	CE	
Cynoscion squamipinnis (Günther, 1867)	52	0.14	0.19	33.3	OV	
Cynoscion xanthulus Jordan & Gilbert, 1882	32	0.61	0.81	50	CE	
Larimus pacificus Jordan & Bollman, 1890	61	0.03	0.00	16.7	OV	
Menticirrhus panamensis (Steindachner, 1877)	19	1.27	2.90	50	CE	
Micropogonias altipinnis (Günther, 1864)	51	0.15	3.85	33.3	CE	
Micropogonias megalops (Gilbert, 1890)	2	8.56	1.68	50	CE	X
Umbrina analis Günther, 1868	24	0.97	0.46	16.7	OV	
MULLIDAE						
Pseudupeneus grandisquamis (Gill, 1863)	60	0.04	0.04	33.3	CE	
GOBIIDAE						
Bollmania stigmatura Gilbert, 1892	57	0.07	0.01	16.7	OV	
Gobionellus microdon (Gilbert, 1892)	61	0.03	0.005	16.7	OV	
EPHIPPIDAE						
Chaetodipterus zonatus (Girard, 1858)	27	0.80	0.70	33.3	CE	
SPHYRAENIDAE						
Sphyraena ensis Jordan & Gilbert, 1882	58	0.06	0.19	16.7	OV	
SCOMBRIDAE						
Auxis thazard (Lecepède, 1800)	58	0.06	1.71	16.7	OV	
Scomberomorus sierra Jordan & Starks in Jordan, 1895	7	3.26	10.89	50	CE	X
PARALICHTHYIDAE						
Citharichthys fragilis Gilbert, 1890	48	0.23	0.07	16.7	OV	

Table 2. Continued / Continuación

Family/Species	Rank	N%	B%	FO%	Life history	Dominant species
Citharichthys gilberti Jenkins & Evermann, 1889	30	0.63	0.28	50	CE	
Cyclopsetta querna Jordan & Bollman, 1890	60	0.04	0.02	16.7	OV	
Etropus crossotus Jordan & Gilbert, 1882	20	1.24	0.23	66.7	RE	X
Etropus peruvianus Hildebrand, 1946	41	0.37	0.09	33.3	CE	
Paralichthys woolmani Jordan & Williams, 1897	54	0.11	0.11	50	CE	
Syacium ovale (Günther, 1864)	37	0.44	0.24	83.3	RE	
PLEURONECTIDAE						
Hypsopsetta guttulata (Girard, 1856)	54	0.11	0.09	50	CE	
Pleuronichthys ocellatus Starks & Thompson, 1910	51	0.15	0.03	50	CE	
BOTHIDAE						
Bothus leopardinus (Günther, 1862)	58	0.06	0.002	16.7	OV	
ACHIRIDAE						
Achirus mazatlanus (Steindachner, 1869)	9	2.96	3.25	100	RE	X
CYNOGLOSSIDAE						
Symphurus chabanaudi Mahadeva & Munroe, 1990	34	0.53	0.14	33.3	CE	
Symphurus fasciolaris Gilbert, 1892	61	0.03	0.003	16.7	OV	
Symphurus leei Jordan & Bollman, 1890	63	0.01	0.001	16.7	OV	
BALISTIDAE						
Balistes polylepis Steindachner, 1876	13	2.17	0.28	66.7	RE	X
TETRADONTIDAE						
Sphoeroides annulatus (Jenyns, 1842)	16	1.63	1.33	66.7	RE	X

The most abundant species were the Yellow fin perch *Diapterus brevirostris* Sauvage, 1879 (16.6%), the Bigeye croaker *Micropogonias megalops* Gilbert, 1890 (8.6%), the Darkspot mojarra *Eucinostomus entomelas* Zahuranec, 1980 (7.9%), the Gulf grunion *Leuresthes sardina* Jenkins & Evermann, 1889 (6.4%) and the Bigscale anchovy *Anchovia macrolepidota* Kner, 1863 (4.1%).

According to their life history, 13 resident (RE), 49 cyclical or seasonal (CE), and 33 occasional (OV) species were observed. Resident species made up 35.9% of relative abundance of which *E. entomelas* stands out with 7.9% and *L. sardina* with 6.4%. The cyclical or seasonal species reached 58.6% of relative abundance of which the most important was *D. brevirostris* with 16.6% while the occasional species added 5.48% of relative abundance, of which the most important was the Pacific bumper *Chloroscombrus orqueta* Jordan & Gilbert, 1883 with 1.3%. As to biomass the resident species showed 24.4%, of which *E. entomelas* and *L. sardina* were the most important with 8.3 and 4.1%, respectively. Cyclical species added up to 62.6% of relative biomass, of which the most important were the Green jack *Caranx caballus* Günther, 1868 with 11.4% and the Pacific sierra *Scomberomorus sierra* Jordan & Starks, 1895 with 10.9%. As for occasional species, they reached 13% of biomass, of which the Pacific cownose ray *Rhinoptera steindachneri* Evermann & Jenkins, 1891 stands out with 2.1% and the California butterfly ray *Gymnura marmorata* Cooper, 1864 with 2% of relative biomass.

Seasonal changes of fish communities

Species richness was higher during the autumn 2010 (52 species), spring 2011 (45 species) and 2012 (47 species) (Fig. 2a). Shannon diversity had a similar behavior to richness with higher values in the autumn 2010 (3.19), spring 2011 (2.96) and 2012 (3.21) (Fig. 2b). Evenness showed very similar values in the autumn 2010 (0.81), spring 2011 (0.78), summer 2011 (0.79) and spring 2012 (0.83); the lowest values were observed during the winter 2012 (0.54) and summer 2012 (0.32) (Fig. 2b).

Abundance showed higher values in the autumn 2010 (0.07 ind. m^{-2}), summer 2011 (0.05 ind. m^{-2}) and 2012 (0.04 ind. m^{-2}) (Fig. 2b) where *D. brevirostris* showed a marked dominance with 0.03 ind.m^{-2}, representing 78.8% of abundance compared to the other species. In terms of biomass, the highest values were observed in the autumn 2010 (4.9 g. m^{-2}) and the summer 2011 (2.9 g. m^{-2}) (Fig. 2b); there was no a seasonal trend, because in the summer 2012 a very low biomass was observed (0.46 g. m^{-2}).

The dominance determined by the biological value index (*BVI*) showed the 15 most important species, according to frequency and abundance during the 6 climate season analyzed, accumulating a relative abundance >50%. The species with the highest BVI were *A. macrolepidota* (175), *Achirus mazatlanus* Steindachner, 1869 (155), *Paralabrax maculatofasciatus* Steindachner, 1868 (143), *E. entomelas* (124), and *L. sardina* (109) (Table 2).

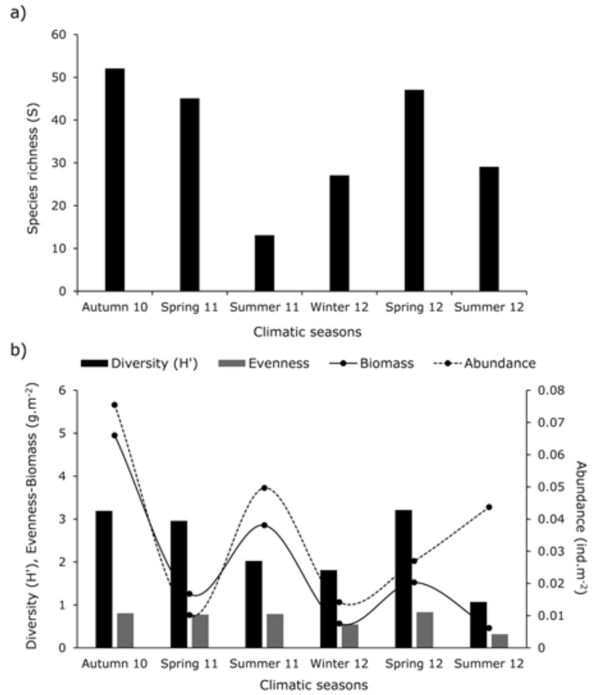

Figure 2. Seasonal variation of a) species richness, b) abundance, biomass, Shannon diversity (*H* ') and Pielou evenness (E) for the 6 climate seasons (autumn 2010, spring 2011, summer 2011, winter 2012, spring 2012, and summer 2012) in the coastal lagoon Las Guásimas, México / Variación estacional de a) riqueza de especies (*S*), b) abundancia, biomasa, diversidad de Shannon (*H'*) y equidad de Pielou (*E*) en las 6 estaciones climáticas (otoño 2010, primavera 2011, verano 2011, invierno 2012, primavera 2012 y verano 2012) en la laguna costera Las Guásimas, México

The RDA indicated that the abundance of the dominant species showed different behaviors in the case of *Eugerres axillaris* Günther, 1864, *P. maculatofasciatus*, *A. mazatlanus*, *E. entomelas*, and *Anchoa nasus* Kner & Steindachner, 1867 showed positive correlation with high salinities (spring and summer 2011) while *Ariopsis seemanni* Günther, 1864 increased its abundance at lower salinity (winter 2012) (Fig. 3). The species related to high temperature were *A. macrolepidota*, *M. megalops* and *Cetengraulis mysticetus* Günther, 1867 (summer 2011 and 2012); on the other hand, *Eucinostomus dowii* Gill, 1863, *Sphoeroides annulatus* Jenyns, 1842, *Balistes polylepis* Steindachner, 1876, *S. sierra*, *Etropus crossotus* Jordan & Gilbert, 1882, and *L. sardina* showed increase in abundance at low temperatures (autumn 2010 and winter 2012) (Fig. 4). The relationship of the ecological parameters and the environmental variables showed that richness and diversity increased in cold temperature while evenness and biomass tended to increase in the climate season with higher salinity, and the increase in abundance was related to higher temperatures (Fig. 3).

The abundance-biomass (ABC) curves showed positive values of statistical *W* in the autumn 2010, spring 2011, summer 2011 and spring 2012; therefore, no stress on the ecosystem was observed while in the winter and summer 2012 the statistical *W* was negative, indicating a moderate stress on the ecosystem during these 2 seasons (Fig. 5).

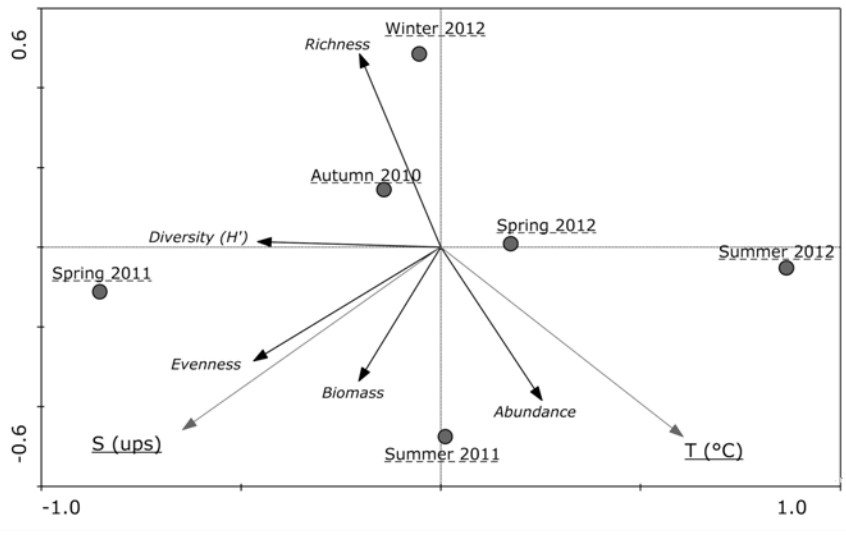

Figure 3. Redundancy analysis (RDA) using ecological parameters (abundance, biomass, species richness, diversity and evenness) and its relationship with environmental parameters of temperature and salinity in the coastal lagoon Las Guásimas, Mexico / Análisis de redundancia (RDA) utilizando los parámetros ecológicos (abundancia, biomasa, riqueza, diversidad y equidad) y su relación con los parámetros ambientales de temperatura y salinidad en la laguna costera Las Guásimas, México

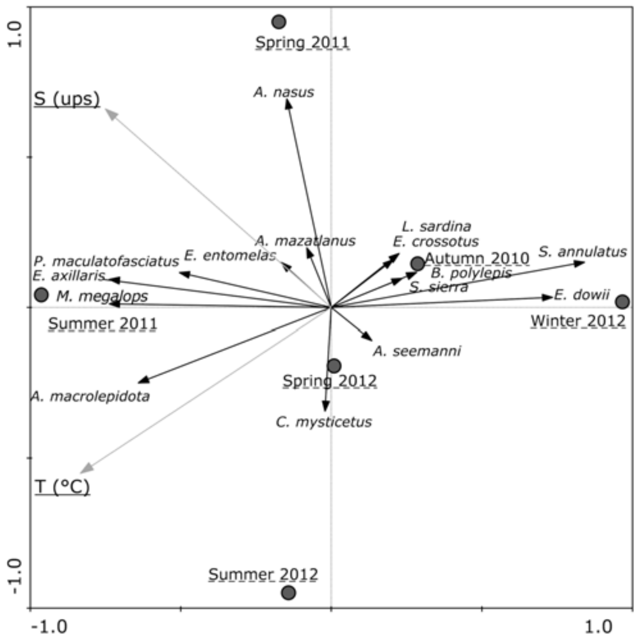

Figure 4. Redundancy analysis (RDA) using the abundances of the dominant species according to BIV and environmental parameters of temperature and salinity in the coastal lagoon Las Guásimas, Mexico / Análisis de redundancia (RDA) utilizando las abundancias de las especies dominantes de acuerdo al IVB y los parámetros ambientales de temperatura y salinidad en la laguna costera Las Guásimas, México

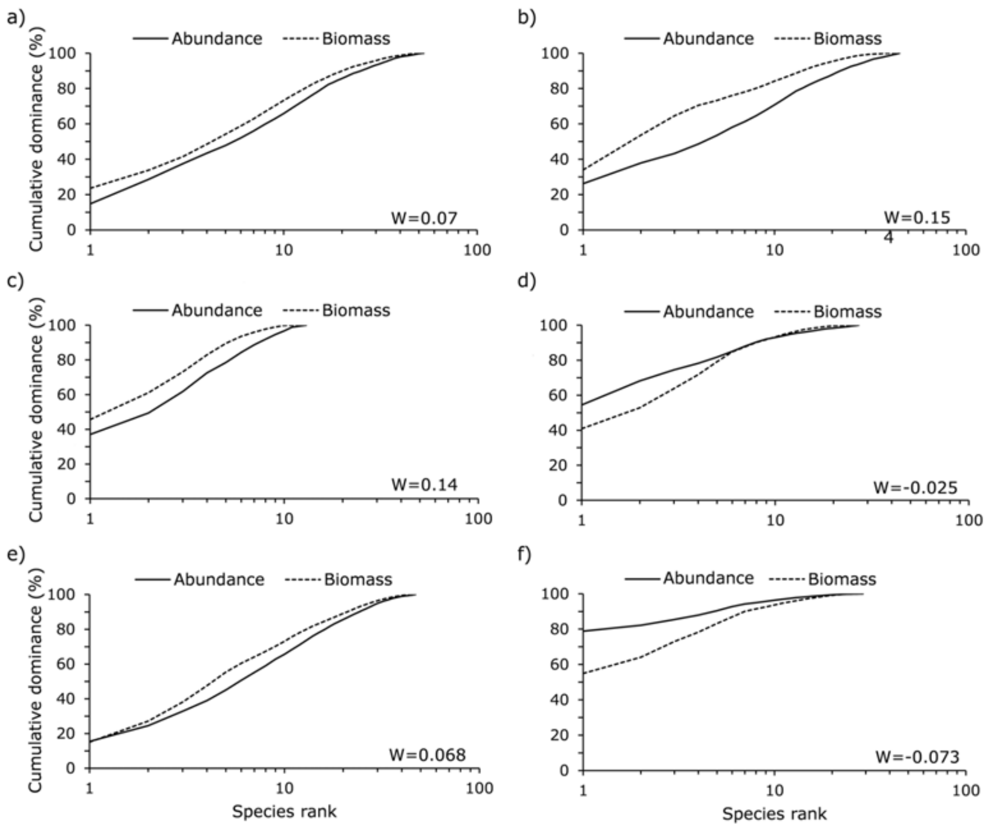

Figure 5. Seasonal variation of the abundance-biomass curves (ABC): (a) autumn 2010, (b) spring 2011, (c) summer 2011, (d) winter 2012, (e) spring 2012, and (f) summer 2012 in the coastal lagoon Las Guásimas, Mexico / Variación estacional de las curvas abundancia-biomasa (ABC): a) otoño de 2010, b) primavera de 2011, c) verano de 2011, d) invierno 2012, e) primavera de 2012 y f) verano de 2012 en la laguna costera Las Guásimas, México

The non-metric MDS analysis identified 4 groups based on abundance with stress of 0.08 and similarity of 20%. Group *a* was integrated by the autumn 2010 and the summer 2011; Group *b* was integrated by the spring 2011 and 2012; and the other 2 groups were integrated by a single sampling period, Group *c* in the summer 2012 and Group *d* in the winter 2012 (Fig. 6). The contrast by ANOSIM showed significant differences in group separation (R= 0.923, P= 0.02). According to the similarity percentages analyses (SIMPER), Group *a* showed a similarity of 20.97% where the species with greater individual contribution were *E. entomelas* (46.8%), *A. macrolepidota* (16.9%), *P. maculatofasciatus* (16.9%), and *A. mazatlanus* (10.2%). Group *b* showed a similarity of 26.1% where the species with greater contribution were *L. sardina* (24.5%), *A. mazatlanus* (11.4%), and *A. macrolepidota* (10.3%). The other groups were not comparable because they were only integrated by a single sampling period.

Discussion

Coastal lagoons work as essential sources of food and energy for many species because many of them spend part or their whole life cycle due to the physical and chemical characteristics of the environment and the great productivity they have (Rodríguez *et al*. 1998). Temperature and salinity in Las Guásimas showed a well-defined semiarid zone seasonality, which agrees with Hernández & Arreola (2007) and Ontiveros (2011). The temperature was influenced mainly by the air temperature with greater variations at 14°C (García 1988). The salinity reported inside the lagoon was greater than that of the ocean, which is the reason for the high evaporation rate and the limited fresh water supply, mainly during the summer and winter months (García 1988, Arreola 2003).

The number of species observed during this study has been the highest reported for this locality (Yépiz 1990, Rodríguez 2010, Ontiveros 2011) and for other lagoons in the state (Thomson 1973, Castro *et al*. 2002). These differences are related to the characteristics of the environment, complexity of the habitat, and sampling effort (Pessanha *et al*. 2003). By employing more methods of collection as in this study, a greater number of species have been obtained, which agrees with Grijalva *et al*. (1996), Amezcua *et al*. (2006) and Galván *et al*. (2010). To date, methods and fishing gear as visual census, gillnets, longlines, hand nets, among others, have been used for collecting fish in lagoons. Clearly, the combination of fishing gear and methods allow obtaining wider information on the structural changes of the community developed over time and thus understand the distinctive ecological and biological processes of the community.

The species observed are mainly species that use the lagoon for feeding and growth, because these areas provide protection from predators at early life stages besides assuring a high availability of food for a number of marine species and juvenile teleosts of subtropical and tropical regions (Kuo *et al*. 2001). The number of cyclic (49) and seasonal (33) species showed that the lagoon is used occasionally and seasonally, behavior that was reflected in the richness, diversity, and biomass indices obtained during our study.

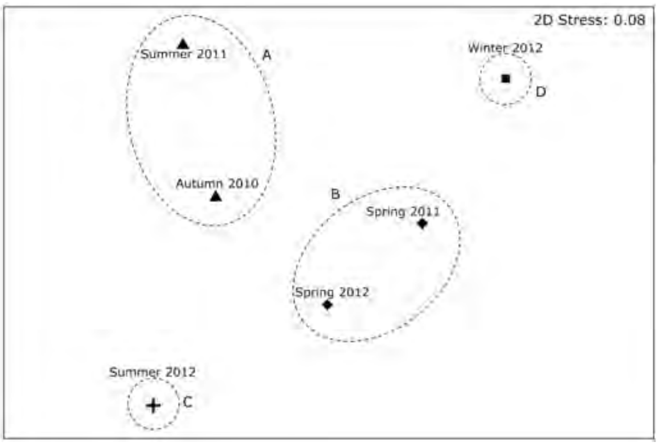

Figure 6. Ordination by the non-metric multidimensional scaling (MDS) of fish assemblage by climate season based on the transformation [log10(X+1)] of the abundance data (where X is the number of individuals m^{-2}) in the coastal lagoon Las Guásimas, Mexico / Ordenamiento por el escalamiento multi-dimensional no métrico (MDS) del ensamble de peces por estación climática, basados en la transformación [log10(X+1)] de los datos de abundancia de cada especie (donde X es el número de individuos m^{-2}) en la laguna costera Las Guásimas, México

Abundance of the fish community showed maximum peaks during summer and autumn, which agrees with Rodríguez (2010) in an analysis of the same lagoon and with González *et al.* (2005) for a mangrove system in the western coast of the GC. Likewise, in a Mediterranean lagoon, abundance was higher during summer and winter (Maci & Basset 2009). In many of the coastal Atlantic and Pacific lagoons, abundance and biomass variations are related to the presence of the ephemeral mouths of these ecosystems and the contribution of temporal rivers. However, in Las Guásimas it could be related to the spawning and recruitment periods, characteristic behavior for the fish community in these environments (Leal 2001). In the summer of 2012, *Diapterus brevirostris* showed dominance in its abundance because its period of reproduction and growth take place within the bodies of water of the lagoon during the warm months (May-August) (Gallardo *et al*. 2015).

Species richness variability is a parameter related to climate seasons while diversity (*H´*) is a response to dominance of a few species during the winter and summer periods as this index is more sensitive to less abundant species (Ludwig & Reynolds 1988, Krebs 1999). Richness and diversity (*H´*) are influenced by several factors, such as climatological period and sampling place and method (Ramírez 1994).

In our study, richness showed a marked dominance seasonally with higher values in autumn and spring, contrary to that reported by González *et al.* (2005) who observed higher species richness in a mangrove system in La Paz BCS in summer and autumn while the greatest richness was seen in winter months and lower in the summer in La Encrucijada lagoon in Chiapas (Velázquez *et al*. 2008). Yépiz (1990) found higher values of richness in autumn and spring, similar trend to that obtained in our study by analyzing the fish community for Las Guásimas with data from 1985-1986. It is possible that this pattern of diversity and richness was a response to a biological process of the species influenced by environmental changes. Las Guásimas provides its ecological role as a breeding and feeding area as well as coastal lagoons of other latitudes, except that its structure shows changes at different times.

The 15 species with the highest biological value (BIV) clearly show the resident species within the lagoon because this index weighs abundance related to frequency, indicating spatio-temporal evidence of the species in the ecosystem (Loya & Escofet 1990). Based on that, dominance of these species is related to their greater occurrence during the different seasons of the year, which has been observed in other lagoons of Northwest Mexico; these species are also common in other lagoons of this region (Rodríguez *et al*. 2011). However some of these species influenced the groups formed according to MDS, as some were evidenced by the analysis of SIMPER, being *Anchovia macrolepidota*, *Achirus mazatlanus*, *Paralabrax maculatofasciatus*, *Eucinostomus entomelas*, *Leuresthes sardina*, among others species that defined the groups.

The abundance-biomass curves (ABC) are a useful tool to assess stress on ecosystems by pollution and currently for fishing. Our results showed a moderate stress during winter and summer of 2012, considering that may be caused to anthropogenic stress (Clarke & Warwick 2001). This method has been used to assess the effects of fishing by Nieto (2010) and Herrera *et al.* (2015) in the Gulf of California. High fishing during summer and autumn in Las Guásimas could cause an effect on the fish community, which explains the behavior of stress observed during winter and summer of 2012 because fishing causes severe disturbances on communities (Blanchard *et al*. 2004, Yemane *et al*. 2005). However, several factors could cause changes; one of them is bathymetry, which could be interpreted as an effect of fishing (Godínez 2003). Thrush *et al.* (2006) suggested that a community can respond to stress levels in relation to the disturbance, which can be caused by factors independent of fisheries, among which seasonal changes, recruitment processes, or life cycle changes of some species are considered. High levels of abundance of *D. brevirostris* in the summer of 2012 showed a process of recruitment and use of the lagoon as a growth area as the organisms were in juvenile stages, explaining the stress observed during this season.

Seasonal changes of ecological parameters observed in our study were related to temperature and salinity according to the RDA analysis. Changes in diversity associated with changes in water temperature have affected the presence and abundance of some species and as reported by Rodríguez *et al.* (2005, 2011). The highest richness and diversity values showed affinity in temperate and cold temperatures, similar behavior to that observed by Acevedo (1997) and De la Cruz (2004) in two lagoons of Baja California Sur where the greatest diversities were observed at high temperatures. The behavior of abundance in relation to warm seasons has been reported by Kuo *et al.* (2001) in a lagoon of Taiwan.

Variations in abundance, biomass, species richness, diversity, and evenness indicate seasonality of species that frequent the lagoon. These seasonal changes are related to the biological processes of species as protection, feeding and growth. Amezcua (2008) mentions in his diagnosis that dominant species observed in this study as *Anchovia macrolepidota, Anchoa nasus, Cetengraulis mysticetus, Ariopsis seemanni, Eucinostomus dowii, E. entomelas, Eugerres axillaris, Micropogonias megalops, Etropus crossotus, Achirus mazatlanus* and *Sphoeroides annulatus* use the lagoon as area of protection, feeding and growth, and *Scomberomorus sierra* uses it only as feeding area. Nonetheless, these processes respond to changes in temperature and salinity.

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