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Seasonal pattern of the fish assemblage of El Conchalito mangrove swamp, La Paz Bay, Baja California Sur, Mexico

Patrones estacionales en la estructura de los peces del manglar El Conchalito, Bahía de La Paz, Baja California Sur, México

Adrián F. González-Acosta[1], Gustavo De la Cruz-Agüero[1],
José De la Cruz-Agüero[1] and Gorgonio Ruiz-Campos[2]

[1]Colección Ictiológica, Centro Interdisciplinario de Ciencias Marinas, I.P.N, Apartado Postal 592, La Paz, Baja California Sur, México, 23000,
E. mail: aacosta@ipn.mx
[2]Facultad de Ciencias, Universidad Autónoma de Baja California, A.P. 1653, Ensenada, Baja California, México, 22800.

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ABSTRACT

The seasonal changes in fish assemblage structure and the importance of El Conchalito mangrove swamp was assessed from October 1996 to August 1997. A modified stationary flume net was deployed at the swamp channel just before high tide and operated continuosly until the neap tide during the full moon. A total of 35,138 fish specimens were caught, belonging to 34 species included in 26 genera and 16 families. The fish assemblage changed with seasons, the fish assemblage had the highest species richness (21) and highest relative dominance index (0.77) in summer, but the highest Shannon diversity (2.7 bits/ind.) and Pielou evenness (0.73) in winter. Fish assemblages of summer and autumn had the highest similarity (68%), which reflects environmental changes that drives a sequential pattern in community structure between summer-autumn and autumn-winter clusters. Dominant species also showed a seasonal alternation between *Eucinostomus currani* (autumn), *Albula nemoptera* (winter) and *Anchoa ischana* (spring and summer) by numbers, whereas *Diapterus peruvianus* (autumn), *Mugil curema* (winter), *Sphoeroides annulatus* (spring) and *A. ischana* (summer) were the dominant species by biomass. The structural analysis of the fish community revealed four dominant species, seven common species and 23 rare species. The importance of the mangrove area of El Conchalito estuary is demonstrated based on the diversity of marine fishes that use this ecosystem as primary habitat for nursery, foraging and recruitment areas, and by its low disturbed conditions.

Key words: Fish assemblage, community structure, Mangrove, Baja California Sur.

RESUMEN

Para evaluar los cambios estacionales en la estructura de las asociaciones de peces y la importancia de el manglar El Conchalito, se realizaron una serie de colectas por estaciones del año, durante el periodo comprendido entre Octubre de 1996 y Agosto de 1997. En los muestreos se utilizó una red de flujo, tipo “flume net” colocada en el canal de entrada al sistema, justo antes de la pleamar y recogiéndola antes del reflujo, en los días de luna llena de cada mes. Se obtuvieron un total de 35,138 ejemplares de peces, pertenecientes a 34 especies, 26 géneros y 16 familias. Se detectó un patrón estacional en la estructura, con la mayor riqueza de especies (21) y de dominancia relativa (0.77) durante el verano, aunque los valores máximos del índice de diversidad de Shannon (2.7 bits/ind.) y de la equidad de Pielou (0.73), correspondieron al invierno. Las asociaciones de peces para el verano y otoño, presentaron la mayor similitud (68%), lo cual es un reflejo de los cambios ambientales que propician un patrón secuencial en la estructura estacional verano-otoño e invierno-primavera. Las especies dominantes alternaron estacionalmente por sus abundancias: *Eucinostomus curani* (otoño), *Albula nemoptera* (invierno) y *Anchoa ischana* (primavera y verano), mientras que *Diapterus peruvianus* (otoño), *Mugil curema* (invierno), *Sphoeroides annulatus* (primavera) y *Anchoa ischana* (verano), fueron las dominantes por sus grandes biomasas. El análisis de la estructura de las asociaciones de peces proporcionó una clasificación formada por cuatro especies dominantes, siete comunes y 23 clasificadas como raras. La importancia del manglar El Conchalito, se demuestra con base en la diversidad de los peces que utilizan este ecosistema como hábitat primario de crianza, alimentación y reclutamiento, así como por su condición ecológica poco alterada.

Palabras clave: Asociaciones de peces, estructura comunidad, Manglar, Baja California Sur.

INTRODUCTION

Mangrove swamps as critical habitats for a great diversity of marine fishes caught by commercial and recreational fisheries, have been demonstrated worldwide (e.g. Pinto, 1987; Henderson, 1988; Lin & Shao, 1999; Kuo *et al*., 2001). The ichthyofauna associated with the mangrove swamp biotopes have well studied along the Atlantic coast of America (Cattrijsse *et al*., 1994); however, few studies exist along the Mexican Pacific coast (e.g. Warburton, 1978; D´Croz & Kwiecinski, 1980; Álvarez-Rubio *et al*., 1986; Amezcua-Linares *et al*., 1987; Flores-Verdugo *et al*., 1990).

Urban centers have often developed in estuaries and few estuaries remain unaffected by human activities (Lindegarth & Mosking, 2001). El Conchalito, is a mangrove swamp located adjacent to the city of La Paz, Baja California Sur, México, currently subject to negative anthropogenic impacts (e.g. garbage and miscellaneous pollution, uncontrolled recreational uses and transit of vehicles). The significance of this mangrove biotope has been demonstrated for several fish species that use this ecosystem for feeding (e.g. lutjanids, carangids and mugilids), nursery (gerreids, engraulids and sciaenids), and recruitment (e.g. clupeids, haemulids, engraulids and gerreids) (González-Acosta, 1998).

El Conchalito mangrove swamp and its bordering wetlands are proposed for protection by municipal authorities of the city of La Paz; however, detailed studies in this area are needed in order to generate basic information to establish an efficient management program (e.g. Snedaker, 1989; John & Lawson, 1990). In the present work, the community structure of the ichthyofauna in El Conchalito mangrove swamp was studied to generate ecological information useful to assess community changes and environmental quality (Tremain & Adams, 1995).

MATERIALS AND METHODS

Study Area. El Conchalito mangrove swamp is located between 24º 08' 34''- 24º 07' 40'' N and 110º 21' 04''-110º 20' 35'' W (Fig.1). It has a communication with La Paz lagoon through a channel 10 m wide, 476 m long, and 0.7 m mean depth, that diminishes toward the head of the channel; tidal intervals are approximately one meter in amplitude.

Climatic conditions in the region are arid and desertic, with 219 mm and 2387mm of annual precipitation and evaporation, respectively. This unbalanced rate in the aquatic environment of the swamp produces high salinity values, hence of El Conchalito must be considered as an antiestuary. Mangrove trees are represented by *Avicennia germinans* (Linnaeus), *Rizophora mangle* (Linnaeus) and *Laguncularia racemosa* (Linnaeus) that borders the tidal channel and with a coverage of 18.5 hectares (González-Acosta, 1998).

Fish sampling. Fish sampling was carried out on October 1996 (autumn), March 1997 (winter), May 1997 (spring) and August 1997 (summer), at the mouth of the tidal channel of El Conchalito mangrove swamp, during days with full moon and hours of high tide. Fish were caught with a stationary “flow net,” (e.g. “flume net” by McIvor & Odum, 1986). Flow net is formed by two wings of 15 m long by 1.5 m wide. The wings were fixed to a frame forming the vertex of a “V.”

The bag net (1.5 x 1.5 m and 4 m long) was attached to a frame and the net closed just before the beginning of the reflux of the high tide. The flow net was built with a silk-nylon net, with a mesh of 6 mm and supported by iron post.

Flow net was operated around 6 hr from the beginning of tidal reflux until the ebb tide; fish were collected from the bag end at intervals of 1 or 2 hrs, preserved with formalin (10%), then deposited in plastic bags with collecting data and finally brought to laboratory for analysis.

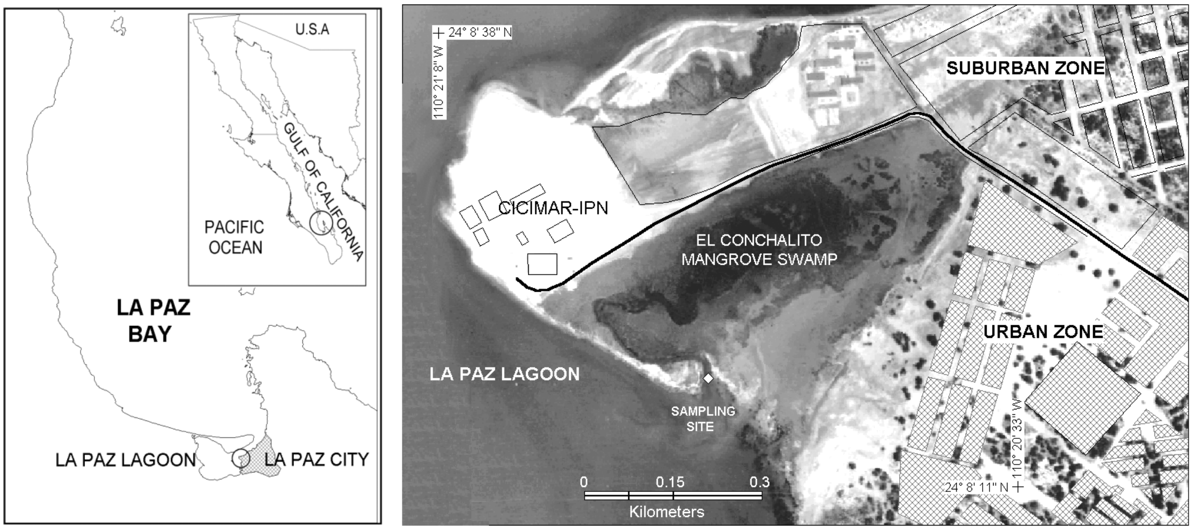

Figure 1. Localization of El Conchalito mangrove swamp, La Paz lagoon, Baja California Sur, Mexico.

Fish were taxonomically determined by general and specialized identification keys (see González-Acosta *et al.*, 1999). All individuals were counted and weighted by species; voucher specimens of each species were deposited and catalogued in the Ichthyological Collection (CI) of CICIMAR-IPN [series CI: 4730-4789].

Data analysis. Number of individuals and biomass for each species were normalized taking in account the total flooded area of the swamp (Varnell & Havens, 1995) and expressed in individuals or weight per square meter, respectively (Table 1). The structure of fish assemblages was determined by means of relative dominance and diversity indices, as well as specific association (Ludwig & Reynolds, 1988).

Species richness (S) was considered as the number of fish species identified in each sample (Brower & Zar, 1977); the species-family ratio (S/F), was applied to characterize the fish fauna following Laroche *et al*. (1997). Shannon-Wiener's diversity (H') index as well as the Pielou's evenness (J') index were used to describe the relation between species richness and abundance distribution among species in each season (Ludwig & Reynolds, 1988).

In order to obtain more information about the relationship between diversity and evenness, specific dominance was calculated using the expression D=1-J'; when D tends to zero, the dominance drops, but if D is near or equal to 1, the dominance is high (Brower & Zar, 1977).

The species similarity in the seasonal composition of the fish assemblage was calculated using Sorensen's community coefficient [SCC]. This index provides a qualitative measure of the relationship between the species and their environment (beta diversity) and considers the number of species shared between both communities. Two communities will be identical when the value of the coefficient is equal to 1.0 (Magurran, 1988). The expression used for the SCC calculation is:

$$scc = \frac{2\,(shared\ species)}{species\ of\ community\ 1 + species\ of\ community\ 2}$$

The ecological status of each fish species within the community was established by means of a graphic analysis between the average of relative abundance of each taxon (axis X) against its percentage frequency of occurrence (axis Y), based on the Olmstead-Tukey's test (Sokal & Rohlf, 1969). A logarithmic scale (ln) was used in both axes to show the trends of either abundance or occurrence. This graphic analysis allows to establish an ecological and quantitative classification of the species in the area, which is based on species abundance and frequency of occurrence data (González-Acosta, 1998). Thus, four ecological categories result of this classification:

A) Dominant: Species with values of relative abundance and relative frequency of occurrence higher than the arithmetic mean for both parameters.

B) Common: Species whose relative frequency of occurrence is higher than the corresponding arithmetic mean.

C) Occasional: Species whose relative abundance is higher than the corresponding arithmetic mean.

D) Rare: Those species whose values of relative abundance and relative frequency of occurrence are lower than their respective arithmetic means.

Table 1. Abundance of fish species collected in El Conchalito mangrove swamp: d=density (organisms/ha), b= biomass (grams/ha), EC =Ecological classification (D =dominant; C = Common; R = Rare), and f = frequency of occurrence in the study period

Family/species	autumn d (b)	winter d (b)	spring d (b)	summer d (b)	EC [f]
ACHIRIDAE					
Achirus mazatlanus (Steindachner)			0.09 (2.8)		R[1]
ALBULIDAE					
Albula nemoptera (Fowler)		4.72 (1.34)	0.09 (0.02)		R[3]
CARANGIDAE					
Caranx sexfasciatus Quoy & Gaimard				0.36 (0.8)	R[2]
Oligoplites saurus (Bloch & Schneider)	0.72 (2.27)			0.27 (0.19)	R[4]
CHANIDAE					
Chanos chanos (Förskaal)	0.09 (0.5)				R[2]
CLUPEIDAE					
Lile stolifera (Jordan & Gilbert)	0.09 (0.12)	0.36 (1.57)	11.4 (79.0)	12.36 (85.7)	C[6]
ENGRAULIDAE					
Anchoa ischana (Jordan & Gilbert)	14.36 (3.65)		51.1 (31.1)	467 (168.2)	D[6]
Anchoa lucida (Jordan & Gilbert)	0.6 (0.24)	0.09 (0.16)		3.45 (71.3)	C[5]
Engraulis mordax Girard			0.09 (0.67)		R[1]
GERREIDAE					
Diapterus peruvianus (Cuvier)	357.6 (238)	0.36 (1.12)	1 (1.35)	7 (12.29)	D[8]
Eucinostomus currani Zahuranec en Yáñez	541.6 (225.9)	0.8 (0.18)	7.45 (13.9)	89.4 (26.27)	D[8]
Eucinostomus dowii (Gill)	15.8 (20.46)	0.09 (0.26)		0.63 (0.35)	C[7]
Eucinostomus entomelas Zahuranec en Yáñez	80.2 (122)	0.36 (1.27)	2 (3.1)	7.6 (11.8)	D[8]
Eucinostomus gracilis (Gill)	34.9 (28.5)		0.09 (0.12)	1.63 (0.8)	C[4]
Gerres cinereus (Walbaum)	1.81 (1.09)		0.09 (0.45)		R[3]
GOBIIDAE					
Ctenogobius manglicola Jordan & Starks	1.5 (0.2)				R[1]
Ctenogobius sagittula Günther	10.8 (3.35)	1.45 (0.90)	0.18 (0.39)	1.18 (0.48)	C[7]
Evorthodus minutus Meek & Hildebrand	1.6 (0.3)				R[1]
Gillichthys mirabilis Cooper		0.18 (0.06)			R[1]
Quietula y-cauda (Jenkins & Evermann)		0.18 (0.05)	0.09 (0.01)		R[2]
HAEMULIDAE					
Conodon serrifer Jordan & Gilbert				0.09 (0.02	R[1]
Haemulon maculicauda (Gill)				3.72 (2.43)	R[1]
Orthopristis chalceus (Günther)				3.45 (2.02)	R[1]
Pomadasys bayanus Jordan & Evermann	0.6 (1.3)			0.8 (1.79)	R[4]
Pomadasys branickii (Steindachner)				1.45 (1.84)	R[1]
Pomadasys macracanthus (Günther)			0.09 (59.8)	0.63 (19.9)	R[3]
HEMIRHAMPHIDAE					
Hyporhamphus naos Banford & Collette				1.09 (1.53)	R[3]

Table 1.Contiation

LUTJANIDAE					
Lutjanus argentiventris (Peters)	0.09 (0.19)			0.18 (0.1)	R[3]
Lutjanus novemfasciatus Gill	0.18 (0.42)				R[1]
MUGILIDAE					
Mugil curema Valenciennes	13.27 (10.72)	4.18 (1.68)	2.54 (5.43)	4.63 (5.58)	C[7]
OPHICHTIDAE					
Mirychthys tigrinus Girard			0.09 (16.9)		R[1]
SCIAENIDAE					
Micropogonias ectenes (Jordan & Gilbert)	0.8 (1.69)				R[2]
SYNGNATHIDAE					
Syngnathus auliscus (Swain)	0.18 (0.04)	0.54 (0.4)			R[2]
TETRAODONTIDAE					
Sphoeroides annulatus (Jenyns)	0.7 (237.3)		0.36 (92.1)	0.09 (16.3)	C[7]
					Total
Total by season	1077 (896)	14.1 (11)	76.8 (313)	606.8 (430)	
Density (m2)	0.107	0.001	0.007	0.06	0.31
Biomass (m2)	0.0896	0.0010	0.0313	0.043	0.33
Diversity (H’)	1.86	2.7	1.65	1.28	2.32
Evenness (J’)	0.43	0.73	0.41	0.29	0.46
Species Richness (S)	20	13	16	21	34
Dominance (1-J’)	0.56	0.27	0.58	0.7	0.54
Species/Families (S/F)	1.8	1.6	1.6	2	2

The parameters of the fish assemblage and its attributes were calculated using the ANACOM (*ANAlisis de COMunidades*) package (De la Cruz-Agüero, 1994).

RESULTS

A total of 35,138 fish specimens (weighting 35.040 kg) was collected in the study area. The fish community was composed of 34 species belonging to 16 families and 26 genera. The most diverse families of the fish assemblage were Gerreidae and Haemulidae with six species and three genera each, followed by Gobiidae with five species and four genera.

Fish abundance. The highest fish total density (0.107 org/m^{-2}) and biomass (0.089 g/m^{-2}) was found in autumn, and the lowest density (0.0014 org/m^{-2}) and biomass (0.009 g/m^{-2}) in winter (Table 1). On the basis of the relative abundance of fish species caught in the study area, an alternation in the composition of dominant species was evident (Fig. 2); *Eucinostomus currani* was the most abundant species in the assemblages during autumn with 50.2% of the total density (Fig. 2a), followed by *Diapterus peruvianus* (33.2%). In winter *Albula nemoptera* was the most important taxon in density (33.3%), followed by *Mugil* curema (29.4%), both representing 62.7% of the overall fish catch for this season (Fig. 2b).

In spring *Anchoa ischana* and *Lile stolifera* dominated in relative density of the fish assemblage (Fig. 2c), with 66.5% and 14.9%, respectively. Again, during summer *A. ischana* was the dominant species with a density of 76.8% (Fig. 2d).

Based on the seasonal variation of the biomass *D. peruvianu*s (26.5%), *Sphoeroides annulatus* (26.4%), and *E. currani* (25.2%) were the dominant species in autumn (78.1% of the total biomass, Fig. 2e). During winter, the dominance was shared by five species, *M. curema* (17 %), *L. stolifera* (15.9%), *A. nemoptera* (13.5%), *Eucinostomus entomelas* (12.8%), and *D. peruvianus* (11.3%), which represented 79.5% of the total biomass (Fig. 2f).

In spring, the fish assemblage was dominated by *S. annulatus* (30.1%) and *L. stolifera* (11.3%), both contributing with 55.9% of the total biomass (Fig. 2g). In summer *A. ischana* was the most dominant taxon (39.1%), followed by *L. stolifera*

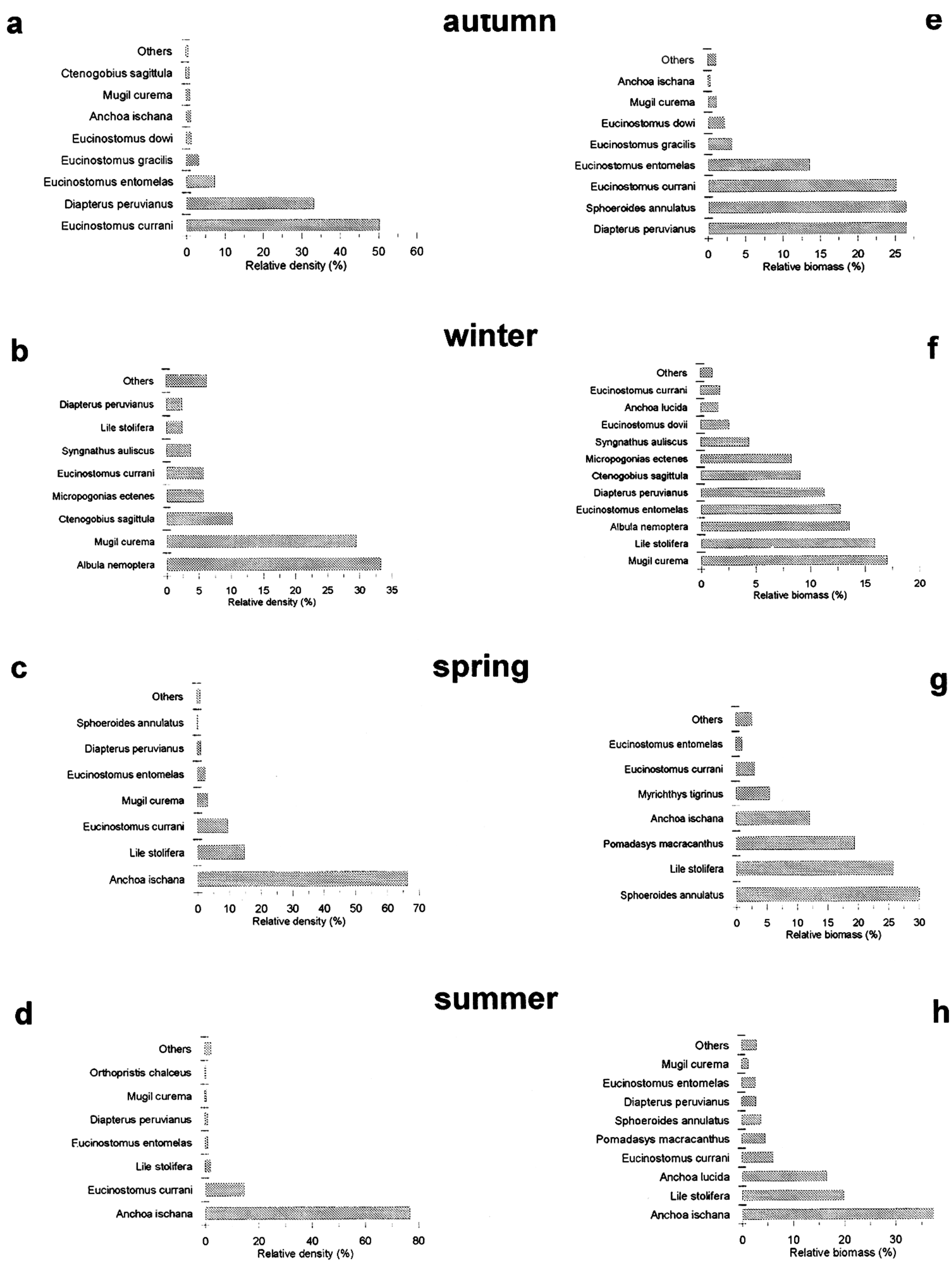

Figure 2. Dominance based on relative density and biomass of fishes in El Conchalito mangrove swamp.

(19.9%), and *Anchoa lucida* (16.5%), all of them representing a 75.5% of the total biomass collected (Fig. 2h).

Species richness and ecological diversity. The highest number of species (21) was registered during summer, most of them belonging to Gerreidae and Haemulidae families. In contrast, the lowest number of species (13) was detected in winter, with a predominance of the gerreid fishes. Variation in the number of species from each sampling period reflects a seasonal pattern in the assemblage specific composition. This pattern decreases from winter to spring, then increasing in summer and decreasing in autumn, to increase again during the winter season (Table 1).

Based on the Shannon-Wiener's diversity index (H'), the highest ecological diversity was recorded in winter (2.7 bits/ind.) and the lowest in summer (1.28 bits/ind.). In the other hand, the dominance index (D') had its highest value in summer (0.77) and the lowest in winter (0.27). Evenness shows a direct relation with ecological diversity whereas dominance values evidence an inverse relation with both ecological diversity and evenness indexes (Table 1).

Table 2. Matrix of Sorensen's Similarity Coefficient of Community in El Conchalito mangrove swamp.

Seasons	autumn	winter	spring	summer
autumn	1	48	55	68
winter		1	55	47
spring			1	54
summer				1

Ecological classification of the fish assemblage. Fish assemblage similarity assessed by means of Sorensen's Community Coefficient (SCC) between seasons showed the highest similarity among summer and autumn assemblages (68%), with a total sharing of 14 species. The lowest similarity was between the assemblages of summer and winter (47%), sharing eight species. On the basis of SCC's matrix (Table 2), a pattern in the seasonal fish composition is noted: high similarity for summer-autumn follows in orders of magnitude by winter-spring, spring-summer, summer-autumn and autumn-winter.

Fish species was ecologically classified into three main groups (Fig.3): Dominant, represented by four species (*A. ischana, D. peruvianus, E. currani* and *E. entomelas*); Common, represented by seven species (*L. stolifera, A. lucida, E. dowii, E. gracilis, C. sagittula, M. curema* and *S. annulatus*), and Rare, represented by 23 species that registered both densities and frequencies of occurrence lesser than their respective means. According to this analysis, none of the fish species from El Conchalito fall within the category of occasional species (Table 1).

DISCUSSION

The number of fish species herein reported for El Conchalito mangrove swamp are less than those found in estuaries and coastal lagoons along the Pacific coast of Mexico (e.g. Warburton, 1978; Maeda *et al*., 1982; Castro-Aguirre & Balart, 1997), and Central America (e.g. Phillips, 1981), this may be became of environmental dynamics and geomorphology of each locality, the sampling effort, as well as preference for a particular habitat by fish (González-Acosta *et al*., 1999).

In El Conchalito mangrove swamp, seasonal estimations of numerical abundance and biomass showed a similar tendency, influenced by predominance of gerreids (density) and tetraodontid fishes (biomass). Flores-Verdugo *et al.* (1990) have mentioned that this variability in the values of density and biomass are greater in the Pacific than in the Atlantic coast, because the existence of ephemeral mouths in the coastal lagoons and the marked influence of seasonality in fluvial contributions. On the other hand, fluctuations in fish density and biomass could also be related to spawn and recruitment periods (Leal de Castro, 2001).

During autumn the fish assemblage of El Conchalito was dominated by the Gerreidae family, mainly *E. currani*. High abundances of gerreid fishes, including those from the genus *Eucinostomus*, are frequently observed in mangrove ecosystems (Álvarez-Rubio et al., 1986; Rooker & Dennis, 1991; Sheridan, 1992) because this fishes enter estuaries for feeding and nursery purposes (De la Cruz Agüero, 2001). The predominance in biomass of *S. annulatus* during autumn is explained by the occurrence of large individuals (≅150 mm SL), during high tides (González-Acosta, 1998). During spring *A. ischana, S. annulatus*, and *Pomadasys macracanthus* were the predominant species in the fish assemblage because their high biomasses. The predominance of *A. ischana* in summer perhaps is associated with the increase of the zooplankton densities during this season. D'Croiz & Wiecinski (1980), mentioned that the anchovies fishery in Panama correspond to the high contribution of mangrove detritus to the productivity of the coastal lagoons. The relative biomass predominance of *L. stolifera* during summer might be associated to the highest levels of primary and secondary productivity in La Paz lagoon for this season (Signoret & Santoyo, 1980).

Species richness showed a seasonal pattern of variation, decreasing from autumn to winter, that may be a consequence of local factors (e.g. salinity, rainfall) unfavorable environmental conditions and migratory movements (Laroche *et al*., 1997; Leal de Castro, 2001). A recurrent tendency in the seasonal fish composition was also noted, which corresponds with the coefficients of similarity calculated (Table 2). Similar patterns have also been reported in other coastal environments from Mexican Pacific (Álvarez-Rubio *et al*., 1986), and Central America (Phillips, 1981).

The variability in the composition of the dominant species, suggest that the competition is reduced among species with similar habits, through the chronological use of the available resources in the ecosystem (Tzeng & Wang, 1992).

The average species-family (S/F) coefficient corresponds to an estuary of warm type (Laroche et al., 1997). The variation observed in the *S/F* ratio between 1.6 (winter and

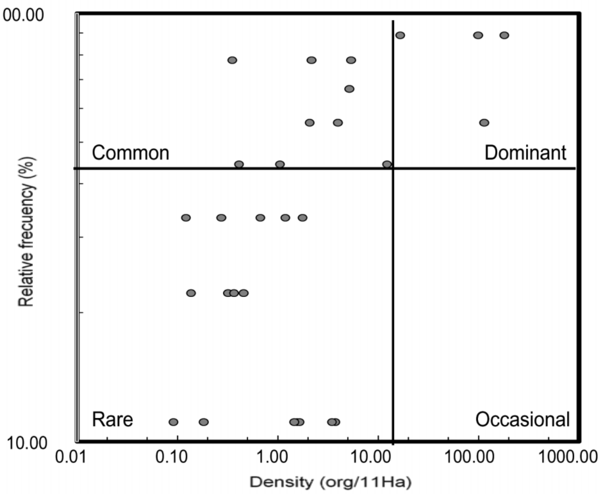

Figure 3. Ecological classification based on relative density and frequency of fish species collected in El Conchalito mangrove swamp.

spring: temperate-cold estuary) and 2.0 (summer: warm estuary), reflect the influence of the seasonal climatic changes on the fish assemblages. The values of diversity index (H') had a seasonal trend that also was related to seasonal values of dominance (D') and evenness (J'). The values of H' recorded for El Conchalito were higher than those reported for wetlands of Panama (D'Croiz & Wiecinski, 1980), El Salvador (Phillips, 1981), and Nayarit, Mexico (Álvarez-Rubio *et al*., 1986) but lower than in Sinaloa, Mexico (Warburton, 1978). Although these ecological attributes of the fish assemblage, could be influenced by circadian and seasonal cycles (e.g. trophic, reproductive and migratory behavior), differences or variations on that indices have been also related to sample size, gear dependence and some other environmental factors (Rochet & Trenkel, 2003).

Ecological classification grouped the fish species from El Conchalito into three categories (Table 1 and Fig. 3): four dominant species corresponds to resident or constant organisms in the estuarine ecosystems, characterized by its ample tolerance to environmental variability (Day *et al*., 1989); seven species were classified as common and belongs to eurihaline marine species, dependent of estuaries (Warburton 1978); none species was classified as occasional, which corresponding to migratory species, or not estuarine-dependent marine fish (Moyle & Cech, 1988); and twenty-three species grouped as rare, correspondig to the transients or non estuarine-dependent described by Thompson & Forman (1987).

Near one half of caught species are commercially important in the region (*c.f.* Ramírez, 1997) suggesting the importance of this ecosystem for supporting the fishery resources in the coastal lagoon and adjacent bay. The occurrence of economically important species is common in estuaries and coastal lagoons (Day *et al*., 1989), due to the great abundance of food resources provided by these ecosystems.

The importance of the mangrove area of El Conchalito estuary could be claimed on the basis of the diversity of marine fishes that use this ecosystem as primary habitat of nursery, or foraging and recruitment areas, and by its low disturbed conditions. We propose the need of an integral managing plan for El Conchalito estuary, in order to establish measures of conservation for one of the less impacted mangrove biotope in La Paz Bay, as well as the prevention of possible anthropogenic impact caused by the urban development of La Paz city.

Managing and conservation programs could permit an appropriate use of fish resources, which should be related to knowledge of the environmental factors that determinate the patterns of distribution and abundance of the fish species of commercial interest (Kupschus & Tremain, 2001). In this sense, diversity and structural indices as used here, combined with other biological metrics, that include both functional grouping and specific species as indicators of estuarine health (e.g. number of spawners, residents and nursery species) have been used in the assessment of the condition of estuarine ecosystem (Tremain & Adams, 1995), because that indices show a strong negative correlation with habitat degradation (Deegan, 1993).

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