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(RESEARCH ARTICLE)

Composition, distribution and relative abundance of fishes linked to fringing reefs of southern Veracruz, Gulf of Mexico

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Abstract

The biological knowledge of the reef communities of southern Veracruz is fundamental, because, according to the Mexican National Commission for the Knowledge and Use of Biodiversity, they are part of a priority marine zone. This paper describes the ichthyological components of the southern Veracruz fringing reefs, including information on abundance and distribution. 146 random visual censuses were conducted in 5 habitats characterized by the dominant benthic groups and environmental features (structural complexity, transparency, and depth). In each census, fish species were identified and their abundance estimated using 6 ordinal categories. Subsequently, the similarity of the ichthyologic communities with the Jaccard Index was determined. The reef formations of southern Veracruz include 91 fish species, 58 genera, and 31 families. According to their relative abundance, 25 % of the fish species were catalogued as rare, 25 % as uncommon, 23.9 % as occasional, and 22.7 % as common or abundant. The most abundant fish species were: *Stegastes adustus*, *Halichoeres bivittatus*, *Thalassoma bifasciatum*, *Bodianus rufus,* and *Ophioblennius macclurei* while, the families: Epinephelidae, Gobiidae, and Scaridae showed a scarce richness and abundance. The benthic attributes (coral cover) and environmental features of habitats were related to the richness, components, and relative abundance of fishes.

Keywords: Checklist; Fish community; Fringing reefs; Veracruz; Gulf of Mexico

1. Introduction

According to their geomorphology, the coral formations of the Veracruz coast include 3 types of reefs: platform, fringing, and submerged banks [1]. In fringing reefs, discrete environments distributed in a depth gradient have been detected. This has been used to describe the ichthyological distribution patterns given their differences in benthic and geomorphological attributes [2]. Coral cover, structural complexity, and depth are variables that most influence fish richness and abundance [3, 4, 5].

The fish communities associated with platform-type reefs of Veracruz are well documented. However, the ichthyofauna of the fringing reefs is little known, because there is only one study in Hornos Reef [6] located in the center of Veracruz. In the south of Veracruz, there is a series of isolated reef structures that form "El Sistema Arrecifal Los Tuxtlas" (SAT), which was proposed as a marine protected area [7]. These fringing reefs are too included in a priority marine zone of Mexico [8]. This condition implies the need to know their biotic diversity. The biological components of the strip of reefs located in front of the municipalities of Mecayapan and Tatahuicapan, Veracruz are little known. For these reefs, there are recorded, 86 species of mollusks [9], 26 species of echinoderms [10], and a non-native fish species [11].

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The knowledge of fish communities in coral reefs is one of the most important to define conservation strategies in marine protected areas. For that, this research describes the ichthyofauna of the fringing system located in front of the municipalities of Mecayapan and Tatahuicapan, Veracruz, including information on its distribution and relative abundance in 5 habitats.

2. Material and methods

This study was carried out in the fringing reefs located in front of the municipalities of Mecayapan and Tatahuicapan, Veracruz (18°30'00" N, 94°50´00" W) (Figure 1). The reef structure is 3.5 km long and ranges in depth from 2 to 12 m [7].

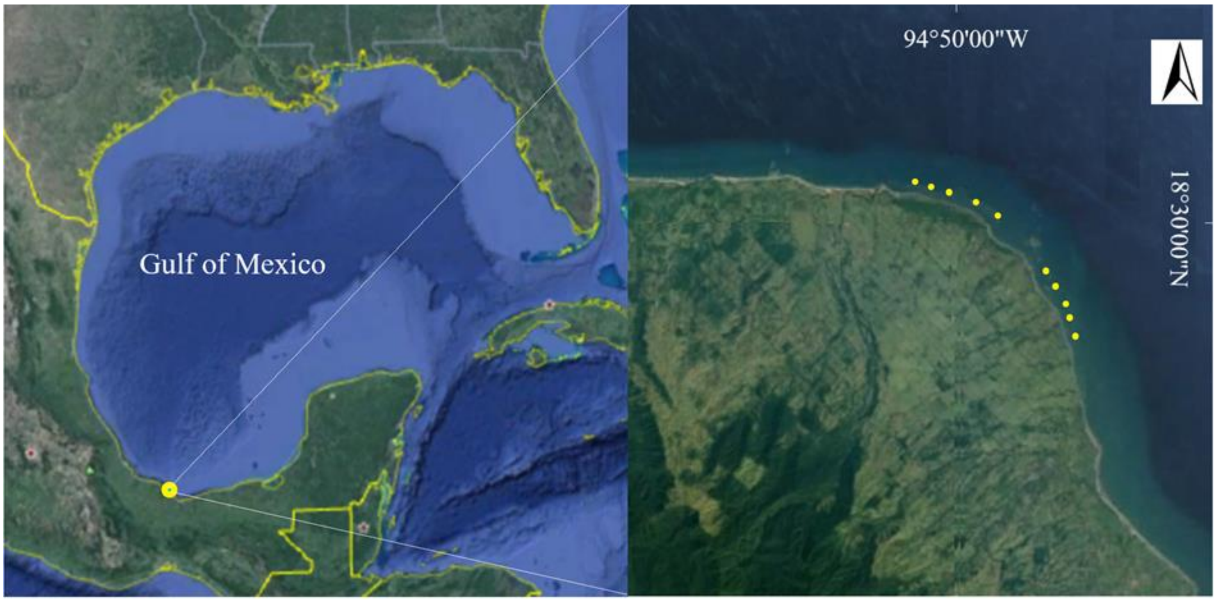

Figure 1 Geographic location of the fringing reefs of southern Veracruz, Gulf of Mexico. Yellow dots corresponded to sampling sites. This map was taken from Google Earth.

From June to September 2013, 146 visual surveys were conducted using the roving diver technique (30 minutes) with SCUBA diving equipment. The sampling was distributed systematically in 10 sites over the reef strip (Figure 1). In each census, fish species were identified using their morphological and coloration patterns that distinguish them. Fish species were ordered systematically according to Nelson *et al*. [12] criteria for supra-generic categories, while genera and families were organized alphabetically. The revision of nomenclature followed the proposal of Fricke *et al*. [13] and the FishBase [14]. Non-parametric models (Chao 2, Jack 1, Jack 2, and Bootstrap) were used to estimate the potential richness with EstimateS version 9.0 [15].

The habitats of fringing reef studied were classified from dominant benthic groups (algae, sponges, corals, and zoanthids) or structures (boat). This information was complemented with data on the structural complexity of reefs and transparency of water, using an ordinal scale with 3 categories (high, intermediate, and low) and with depth data obtained with a dive computer, categorizing it into 2 groups: < 5 m and > 5 m.

Fish species were classified according to their relative abundance in the following categories: Rare (1 record during all expedition); Uncommon (< 5 total records); Occasional (~20 total records at multiple dive sites); Common (recorded at most dive sites); Locally common (scores to tens at 1 to 2 dive sites) and Abundant (tens to hundreds at most dive sites). The presence-absence data by habitat were used to compare the fish communities using the Jaccard Index through the PAST program [16].

3. Results and discussion

The ichthyological fauna associated with the fringing reefs of southern Veracruz described for the first time in this work, it is composed of 91 species belonging to 58 genera and 31 families (Table 1).

Table 1 List of fishes observed on 5 habitats on the southern fringing reef of Veracruz, Gulf of Mexico.

Family	Species	Habitat				
		ROCORA	ROALCO	ROALGA	ROZOCO	BOAT
Urotrygonidae	*Urobatis jamaicensis* (Cuvier, 1816) U	1		1		
Dasyatidae	*Hypanus americanus* (Hildebrand & Schroeder, 1928) U	1			1	
Muraeneidae	*Echidna catenata* (Bloch 1795) U	1		1	1	
	Gymnothorax funebris Ranzani 1839 R				1	
	Gymnothorax miliaris (Kaup, 1856) R	1				
	Gymnothorax moringa (Cuvier, 1829) R	1				
Holocentridae	*Holocentrus adscensionis* (Osbeck, 1765) O	1	1		1	1
	Myripristis jacobus Cuvier, 1829 R	1				
	Neoniphon vexillarium (Poey, 1860) R	1				
Gobiidae	*Coryphopterus glaucofraenum* Gill, 1863 O	1	1	1	1	
	Coryphopterus hyalinus Böhlke & Robins, 1962 U	1		1		
Pomacentridae	*Abudefduf saxatilis* (Linnaeus, 1758) C	1	1	1	1	1
	Chromis multilineata (Guichenot, 1853) U	1	1	1		1
	Chromis scotti Emery, 1968 Lc	1	1	1	1	
	Microspathodon chrysurus (Cuvier, 1830) Lc	1	1	1	1	
	Neopomacentrus cyanomus Bleeker, 1856 Lc	1	1	1	1	
	Stegastes adustus (Troschel, 1865) A	1	1	1	1	1
	Stegastes leucostictus (Müller & Troschel, 1848) R			1	1	
	Stegastes partitus (Poey, 1868) O	1	1	1	1	
	Stegastes xanthurus (Poey, 1860) C	1	1	1	1	

Blenniidae	*Hypsoblennius invemar* Smith-Vaniz & Acero 1980 R					1
	Ophioblennius macclurei (Silvester, 1915) C	1	1	1	1	1
	Parablennius marmoreus (Poey, 1876) O	1	1	1	1	
	Scartella cristata (Linnaeus, 1758) R				1	
Labrisomidae	*Labrisomus nuchipinnis* (Quoy & Gaimard, 1824) C	1	1	1	1	1
	Malacoctenus triangulatus Springer, 1959 R			1		
Carangidae	*Caranx bartholomaei* Cuvier, 1833 O	1	1	1	1	
	Caranx crysos (Mitchill, 1815) U	1		1		
	Caranx hippos (Linnaeus, 1766) R	1				
	Caranx latus Agassiz, 1831 R			1		
	Caranx ruber Bloch, 1793 O	1	1	1	1	1
	Decapterus macarellus (Cuvier, 1833) R					1
	Seriola rivoliana Valenciennes, 1833 R			1		
	Trachinotus goodei Jordan & Evermann, 1896 U	1	1			
Sphyraenidae	*Sphyraena barracuda* (Walbaum, 1792) O	1	1	1	1	
Labridae	*Bodianus rufus* (Linnaeus, 1758) C	1	1	1	1	1
	Halichoeres bivittatus (Bloch, 1791) A	1	1	1	1	1
	Halichoeres burekae Weaver & Rocha, 2007 C	1	1	1	1	1
	Halichoeres maculipinna (Müller & Troschel, 1848) O	1	1	1	1	1
	Halichoeres radiatus (Linnaeus, 1758) C	1	1	1	1	1
	Thalassoma bifasciatum (Bloch, 1791) A	1	1	1	1	1
Scaridae	*Scarus iseri* Bloch, 1789 U				1	
	Scarus taeniopterus Desmarest, 1831 R		1			
	Scarus vetula Bloch & Schneider, 1801 R	1				
	Sparisoma radians (Valenciennes, 1840) O	1	1	1	1	
	Sparisoma rubripinne (Valenciennes, 1840) C	1	1	1	1	

Gerreidae	*Gerres cinereus* (Walbaum, 1792) R	1				
Mullidae	*Mulloidichthys martinicus* (Cuvier 1829) R					1
	Pseudupeneus maculatus (Bloch, 1793) O	1	1	1	1	1
Pempheridae	*Pempheris schomburgkii* Müller & Troschel, 1848 Lc	1		1	1	1
Kyposidae	*Kyphosus incisor* (Cuvier, 1831) C	1	1	1	1	1
Epinephelidae	*Cephalopholis cruentata* (Lacepède, 1802) U			1		
	Epinephelus adscensionis (Osbeck, 1765) C	1	1	1	1	1
Serranidae	*Hypoplectrus puella* (Cuvier, 1828) R			1		
Serranidae	*Serranus subligarius* (Cope, 1870) U	1		1		
Apogonidae	*Apogon pseudomaculatus* Longley 1932 R			1		
Chaetodontidae	*Chaetodon ocellatus* Bloch, 1787 O	1	1		1	1
	Chaetodon sedentarius Poey, 1860 R	1		1		
	Chaetodon striatus Linnaeus 1758 R	1				
Pomacanthidae	*Holacanthus bermudensis* Goode, 1876 R				1	
	Pomacanthus paru (Bloch, 1787) C	1	1	1	1	1
Haemulidae	*Anisotremus surinamensis* (Bloch, 1791) C	1	1	1	1	1
	Anisotremus virginicus (Linnaeus, 1758) C	1	1	1	1	1
	Brachygenys chrysargyreum Günther, 1859 U	1		1		1
	Haemulon aurolineatum Cuvier, 1830 U		1		1	1
	Haemulon carbonarium Poey, 1860 O	1	1	1	1	1
	Haemulon flavolineatum (Desmarest, 1823) U	1		1		
	Haemulon macrostomum Günther, 1859 C	1	1	1	1	1
	Haemulon plumierii (Lacepède, 1801) U			1		
	Haemulon vittatum Poey, 1860 U	1	1			

Lutjanidae	*Lutjanus analis* (Cuvier, 1828) U			1	1	
	Lutjanus apodus (Walbaum, 1792) O	1	1		1	
	Lutjanus griseus (Linnaeus, 1758) O	1	1	1	1	1
	Lutjanus jocu (Bloch & Schneider, 1801) O	1		1	1	1
	Lutjanus mahogoni (Cuvier, 1828) O	1	1	1	1	
	Lutjanus synagris (Linnaeus, 1758) O	1	1	1	1	1
	Ocyurus chrysurus (Bloch, 1791) O	1	1	1	1	1
Scorpaenidae	*Pterois volitans* (Linnaeus, 1758) R	1				
	Scorpaena plumieri Bloch, 1789 U	1		1		1
Ephippidae	*Chaetodipterus faber* (Broussonet, 1782) U				1	
Scianidae	*Odontoscion dentex* (Cuvier, 1830) C	1	1	1	1	
	Pareques acuminatus (Bloch & Schneider, 1801) O	1	1	1	1	
	Pareques umbrosus (Jordan & Eigenmann, 1889) O	1	1	1		
Acanthuridae	*Acanthurus chirurgus* (Bloch, 1787) C	1	1	1	1	1
	Acanthurus coeruleus Bloch & Schneider, 1801 U		1	1	1	1
	Acanthurus tractus Poey, 1860 O	1	1	1	1	
Sparidae	*Archosargus probatocephalus* (Walbaum, 1792) R					1
Monacanthidae	*Cantherhines pullus* (Ranzani, 1842) O	1	1	1	1	1
Tetraodontidae	*Canthigaster rostrata* (Bloch, 1786) C	1	1	1	1	1
	Sphoeroides spengleri (Bloch, 1785) U		1	1		
Diodontidae	*Diodon hystrix* Linnaeus, 1758 U	1			1	1
	Total	**69**	**51**	**64**	**57**	**39**

The letters at the end correspond to abundance categories: R=rare, U=uncommon, C=common, O= occasional, Lc= locally common, and A=abundant.

Its composition is similar to that recorded in the Veracruz platform-type reefs [6, 17, 18]. However, the shallow depth of the fringing reefs investigated (<10 m) may be a limitation for the presence of some common fish species (e. g. *Bodianus pulchellus*, *Prognathodes aculeatus*) of areas deeper than 20 m [19]. Two species from the Indo-Pacific region are included in the list: *Pterois volitans* and *Neopomacentrus cyanomos*. The record of *P. volitans* confirms its distribution throughout Veracruz, from the north [18] to the south [20]. A unique observation of lionfish may be an indicator of its population has not yet settled on these reefs. On the other hand, *N. cyanomos* was seen forming groups of 10 to 22 organisms, as well as it has been referred to EnMedio (North) [21] and Palo Seco Reefs (South) on Veracruz [20], its abundance suggested that it is a well-established population. *Hypsoblennius invemar*, was observed in the exoskeletons of giant barnacle attached to the hull of the Barco Viejo and it is a new record to coral reefs of Veracruz.

The potential richness estimated with non-parametric models was 112 species (Figure 2) and these models explained 81 % of the total richness. The number of species at fringing reefs of southern Veracruz was higher than the records of Pérez-España *et al*. [6] in Hornos Reef (center of Veracruz). The differences were attributed to the fact that the fringing reefs of southern Veracruz are four times longer than Hornos Reef. The richness of the families Pomacentridae, Haemulidae, Carangidae, and Lutjanidae (Table 1) coincides with that recorded in emerging coral reefs [6, 17, 18]. However, the families: Epinephelidae (2 species), Gobiidae (2 species), and Scaridae (six species) showed a low richness (Table 1).

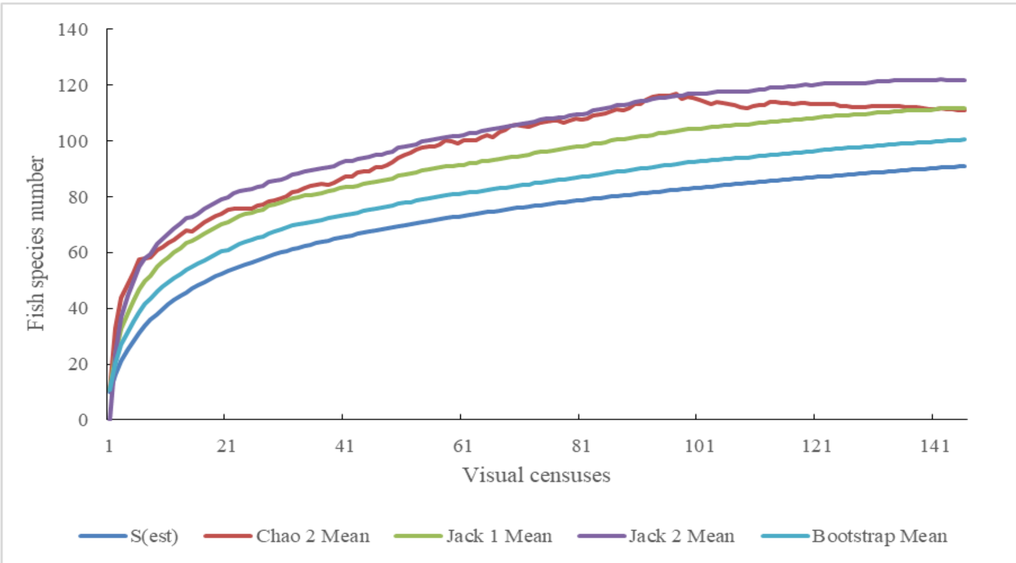

Figure 2 Cumulative curves of the fish richness of fringing reefs of southern Veracruz, Gulf of Mexico according to no parametric models: Chao 2, Jack 1, Jack 2, and Bootstrap.

In the fringing reef system of southern Veracruz 5 habitats were characterized: 1) Rock covered by zoanthids and corals (ROZOCO), characterized by a rock structure covered with *Zoanthus pulchellus* and/or *Palithoa caribaeorum*, with isolated coral colonies of the genera *Siderastrea* and *Pseudodiploria* as well as sea urchins of the genus *Echinometra*. This habitat was shallow (2 to 4 m depth) with transparent waters and a low to intermediate structural complexity (Figure 3A); 2) Rock covered with macroalgae and turf algae (ROALGA) formed by hard rock covered with macroalgae (*Dyctiota*), turf algae, sponges, and sandy areas. The coral cover in this habitat was lesser than 1 %, and depth oscillated between 2.5 and 8.5 m. The structural complexity was low in the plains and high in the slopes, while water transparency was high in shallow areas and media in deep areas with more than 5 m depth (Figure 3 B and C); 3) Sunken boat (BOAT) locality corresponded to the remains of the boat known as "Barco Viejo" that measures approximately 30 m in length and located at 6 m depth. The structural complexity and transparency of the water in this habitat were intermediate (Figure 3 D); 4) Rock covered with macroalgae and corals (ROALCO), was a habitat characterized by a rocky substrate covered with macroalgae (*Dyctiota* and *Galaxaura*) or turf algae, with isolated coral colonies (in the shallow parts) of the genera: *Siderastrea* and *Pseudodiploria*. The edges slopes that reach up to 8.7 m depth presented sandy areas. The structural complexity of this habitat was intermediate, and the water transparency was high in shallow areas and media in deep ones (Figure 3 E and F); 5) Coral-covered rock (ROCORA) corresponded to the rocky substrate that forms labyrinths or mountains with sandy channels. It presented colonies of *Oculina diffusa*, *Pseudodiploria clivosa*, *Pseudodiploria strigosa,* and *Siderastrea siderea*. The depth of this habitat varied between 2.5 and 4.5 m, and its structural complexity was high and presented transparent waters (Figure 3 G and H). These habitats were similar to those determined in the shallow parts of platform-type reefs [22, 23].

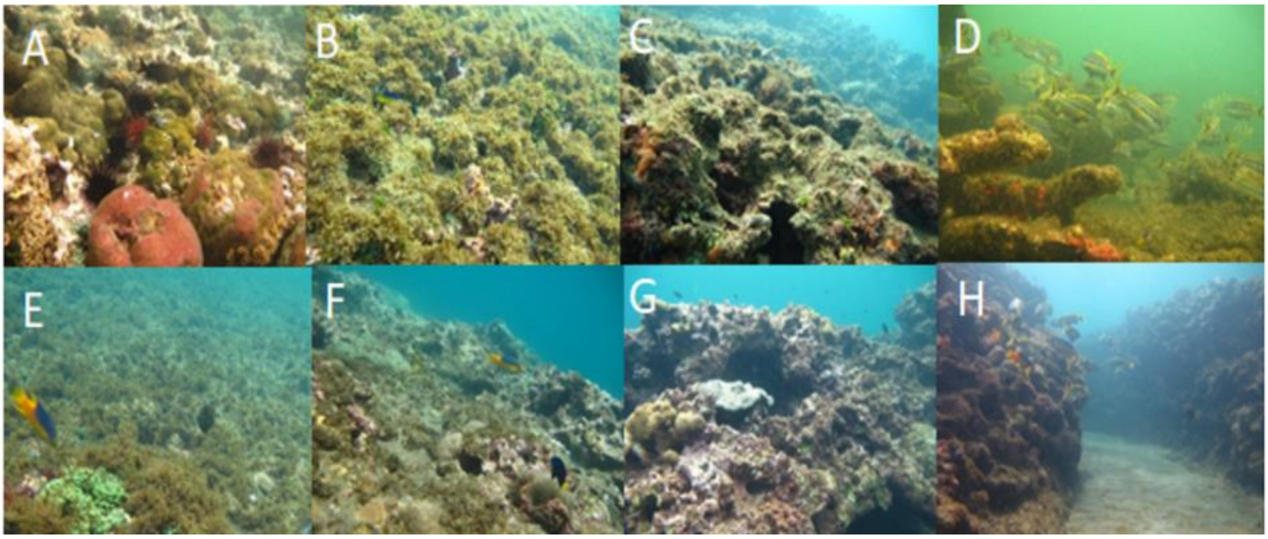

Figure 3 Habitats of the fringing system of southern Veracruz, Gulf of Mexico. A) View of ROZOCO, showing colonies of *Z. pulchellus*, *Siderastrea* sp, and *Echinometra* sp; B) Shallow zone of ROALGA, covered with brown algae (*Dyctiota*); C) Slope of ROALGA, characterized by turf algae and sponges; D) View of sunken boat known as "Barco Viejo" (BOAT); E) View of the shallow zone of ROALCO, covered with brown algae and small coral colonies; F) Slope of ROALCO with brown algae and coral colonies; G) View of the shallow zone of ROCORA, covered with coral colonies, soft corals and sponges; and H) Labyrinthine channels of ROCORA with sandy areas in the bottom and rock walls.

Table 2 Most abundant fish species by habitat, in the southern fringing reefs of Veracruz, Gulf of Mexico.

Habitat	**Shallow zones (<5m)**	**Slopes (>5m)**
ROALGA	*Halichoeres bivittatus, Stegastes adustus, Bodianus rufus, Labrisomus nuchipinnis, and Thalassoma bifasciatum.*	Schools of roving herbivorous: *Acanthurus chirurgus*, *Kyphosus incisor*, and *Sparisoma rubripinne* as well as solitary individuals: *Hypoplectrus puella*, *Chaetodon sedentarius*, and *Pareques acuminatus*.
ROZOCO	*Stegastes adustus, Halichoeres bivittatus, Ophioblennius macclurei, Thalassoma bifasciatum, and Bodianus rufus.*	
ROALCO	*Halichoeres bivittatus, Stegastes adustus, Bodianus rufus, Ophioblennius macclurei, and Sparisoma rubripinne.*	On the slopes: *Chaetodon ocellatus*, *Acanthurus coeruleus* and *Acanthurus chirurgus*. On the sandy bottom were common: *Pareques umbrosus*, *Odontoscion dentex*, and *Serranus subligarius.*
BOAT	*Anisotemus virginicus, Haemulon macrostomum, and Pempheris schomburgkii*	
ROCORA	*Stegastes adustus, Microspathodon chrysurus, Ophioblennius macclurei, Thalassoma bifasciatum, and Labrisomus nuchipinnis*. In the channels were common: *Haemulon macrostomum*, *Haemulon carbonarium*, *Bodianus rufus*, and *Halichoeres bivittatus* as well as schools of: *Acanthurus chirurgus*, and *Abudefduf saxatilis*.	

The shallow habitats, with transparent waters and low structural complexity (ROZOCO, shallow part of ROALGA, and ROALCO), were less rich (Table 1). The ichthyofauna of these habitats was represented by *Halichoeres bivittatus*, *Stegastes adustus*, *Bodianus rufus*, *Labrisomus nuchipinnis*, *Ophioblennius maclurei*, *Sparisoma rubripinne*, *Microspathodon chrysurus,* and *Thalassoma bifasciatum*, as is the case in the plains of the platform type reefs [22, 24]. In contrast, deeper and complex habitats (ROALGA, ROCORA, ROALCO) showed greater ichthyological richness. On the slopes, groups of roving herbivores (*Acanthurus chirurgus*, *Kyphosus incisor,* and *S. rubripinne*) and other species that use the structures as a refuge were observed. A special case was the wreck, where the metallic structure favors the presence of haemulids, labrids, and pomacentrids. In this case, the lower richness seems to be related to its area (approximately 100 m^2), the low structural complexity of the surrounding areas, and the turbidity. The most frequent fish species by reef habitat are shown in Table 2. Extreme environmental conditions may limit the establishment and distribution of ichthyofauna [25], especially of roving herbivores [26, 27].

Jaccard's analysis indicates that the ichthyofaunal components of different habitats were similar. The dendrogram formed 3 groups: one that associated the ROCORA and ROALGA habitats (0.66), another that linked the ROZOCO and ROALCO habitats (0.71), and a third group that corresponded to the BOAT (Figure 4). The similarity of the ichthyofauna of fringing reefs of southern Veracruz is due to their shallowness, structural complexity, and coral cover. The last 2 variables are related to the exposure of fringing reef to the freshwater carried by the streams that originate in the surrounding volcanic zone [7, 28] as well as to the high regional precipitation [29] that reduces salinity, increases the availability of nutrients and decreases the transparency of the water, as occurs in Hornos Reef [6].

The analysis of the relative abundance indicated that of the total fish species, 25 % were cataloged as Rare, 25 % as Uncommon, 23.9 % as Occasional, and 22.7 % were Common or Abundant. The highest number of rare fish species was detected in the ROCORA habitat (15.7 %) and the lowest in the ROALCO habitat (1.96 %). These differences were attributed to structural complexity [30]. On the other hand, the highest proportion of locally abundant fish species was observed in the ROALGA area (7.02 %) due to the presence of schools of *A. chirurgus* and *C. scotti* among other species (Table 1).

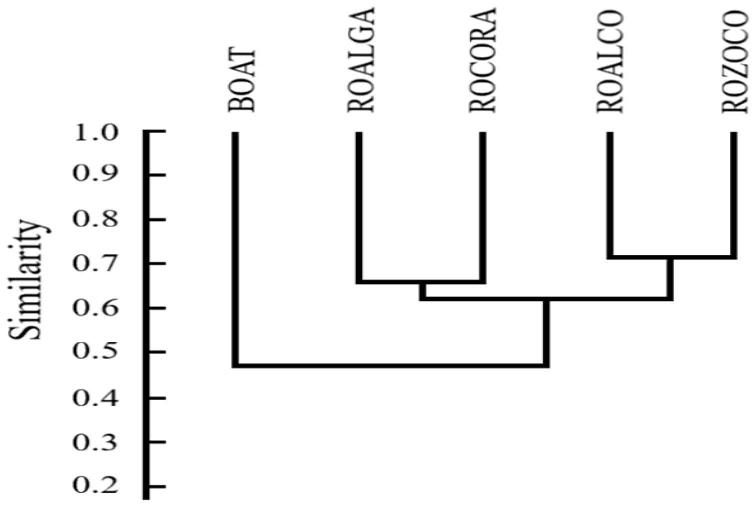

Figure 4 The similarity of fish communities of the fringing system of southern Veracruz, Gulf of Mexico, according to Jaccard's Index.

The scarce richness and abundance of the families: Scaridae, Gobiidae, and Epinephelidae in the fringing reefs of southern Veracruz were similar to the records at Hornos Reef [6]. Among the species with a wide distribution and abundance, highlighted: *Epinephelus adscencionis* and *S. rubripinne*, that suggest a close relationship with reef structures [30, 31, 32] and food availability [33]. The abundance of *S. rubripinne* in the fringing reefs of Veracruz' southern, can be related to its capacity to occupy any reef area (ridge, slope, etc.) together with the fact that it can consume algae of the genera: *Halimeda* and *Dictyota* [34] as well as turf algae [35] which are abundant in the region.

Other factors, such as fishing or processes such as recruitment, may be implicated in the richness of the families Epinephelidae and Scaridae. The effect of fishing on scarids is predictable, as, when it intensifies, the biomass decreases due to the absence of large fish [36], and the same is true on epinephelids. Although there are no fishery data for the region, pressure from this factor does not appear to be important because no juvenile or small-sized stages were observed. On the other hand, larval recruitment has been linked to reproduction. The dispersion produced by marine currents [37] and possibly the natural barrier (anticyclone gyre) that forms in the summer in front of the SAT [38] as well as the quality of the larvae [37] may limit entry and recruitment of fish larvae in the region.

The results of this research reveal that the components and abundance of fish associated with the reef ecosystems of southern Veracruz are related to at least 3 factors: 1) structural complexity, which is a determining in reef fish diversity [31, 32, 39]; 2) river drainage and the regional rainfall regime [28] which decreases salinity and increases water turbidity in the coastal zone. When these coupled with oceanographic dynamics may be unfavorable for fish recruitment and survival [25, 37, 40]; and 3) depth, that separates shallow and deep fish associations [3, 19].

4. Conclusion

The ichthyofauna of the southern fringing reefs of Veracruz was composed of 91 fish species. The richest fish families were: Pomacentridae, Haemuidae, and Lutjanidae. The scarcity of scarids, gobids, and epinephelids was highlighted. The environmental conditions defined by benthic (coral cover) and environmental features (structural complexity, transparency, and depth) in this region seem to be related to composition, distribution, and abundance of fish communities.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The author declare no conflict of interest.

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