

Research Article

Cryptic fish associated with different substrates in two coastal reef communities of Colima, Mexico

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ABSTRACT. It has been established that cryptic fish (CF) contribute to keeping the equilibrium of marine environments, and are also potential indicators of the environment. In the present study, ecological evaluations of CF-associated with reef communities exposed to high or low anthropogenic pressure off the coast of Colima, Mexico (La Boquita-LB, and Carrizales Bay-CA, respectively) were carried out. During 2014 a total of 16 surveys were carried out during winter-spring (WS), and eight surveys were carried out in summer-fall (SF). Three CF surveys were carried out in each reef community, covering a 180 m² area; several ecological indices were calculated, and the benthic habitat was characterized. A total of 3,056 CF belonging to 23 species, 22 genera, and 15 families were recorded. The species *Axoclinus lucillae*, *Acanthemblemaria macrospilus*, *Coralliozetus boehlkei*, *Ekemblemaria myersi*, and *Hippocampus ingens* represented new records for CA and LB. The physiographic and topographic characteristics of the marine substrate were factors that significantly influenced the occurrence of CF, especially those with reduced mobility. There was higher CF richness and diversity during the SF. The species *A. macrospilus*, *C. boehlkei*, and *E. myersi*, associated with rocky environments with high sponge and macroalgae cover, were identified as potential bioindicators of degradation of the benthic habitat. The species *Cirrhitichthys oxycephalus*, *A. macrospilus*, *Coryphopterus urospilus*, and *Elacatinus punctulatus* were associated with coralline, crystalline, and relatively unperturbed environments.

Keywords: cryptic ichthyofaunal; coral reefs; ecological indices; rocky reefs; coral bleaching; bioerosion; cryptobenthic fishes

INTRODUCTION

Reef fish can be divided into two large groups according to their habits and morphological characteristics: cryptic and conspicuous fish (Allen & Robertson, 1998). The latter has been the most studied, as they are free-swimming and easily accessible, and several techniques have been used for their identification and quantification. On the other hand, cryptic fish (CF) also recognized with the term cryptobenthic fishes (CRFs) have previously been defined as ‘adult fishes of typically <5 cm that are visually and/or behaviourally cryptic, and maintain a close association with the benthos’ (Depczynski & Bellwood, 2003). According to Ackerman & Bellwood (2000), CF is perhaps the most poorly understood group of coral reef vertebrates in terms of their biodiversity,

ecology, and evolution. CF represent the ‘hidden half’ of coral reef vertebrate biodiversity. They are hard to observe due to their small size, camouflage colors, erratic behavior, and long residency; this has led to their being less studied (Brandl *et al.*, 2018).

Some limitations of studying cryptic organisms are the negative response of cryptic species towards the presence of divers, their small size, and their camouflage ability, among others making traditional visual surveys difficult, and can also affect the significance level, which can take values of up to 45% (Stewart & Beukers, 2000; Willis, 2001). This problem is exacerbated in complex habitats, such as those found in coral reefs, as cryptic species present there will be even harder to detect and identify. The species in this study were considered cryptic species as they have cryptic habits and a direct association with the substrate,

which corresponds to the definition by Brandl *et al.* (2018).

Cryptic fish fulfill an ecological role in ecosystems as part of the trophic chain, and their feeding habits contribute to maintaining ecosystems in equilibrium (Depczynski & Bellwood, 2003; Brandl *et al.*, 2018). They also have potential as indicator organisms of environmental quality because they reside on specific substrates (Galván-Villa, 2011; Brandl *et al.*, 2018). Regarding the possible influence of environmental variations on the presence of cryptic fish, some authors consider the influence of variables such as temperature (Romero-Ponce, 2002; Zayas-Álvarez, 2005); however, other authors consider that there is no thermodependence, and refer to the complexity of habitats and the abundance of predators as the most influential variables (Beukers & Jones, 1997; Tolimieri, 1998; González-Cabello, 2003).

The type of substrate and modifications to the substrate are critical for these species, as they are ecological specialists that occupy particular niches, and can be susceptible to changing conditions that could impact the availability of refugia, feeding, reproductive capacity, and adaptation (Friedlander & Parrish, 1998; García & Pérez, 2001). It should be mentioned that most of these organisms are not protected in Mexico and are not cataloged as threatened in the red list of the International Union for the Conservation of Nature (<http://www.iucnredlist.org/>). Mainly because there is a lack of knowledge on these organisms. This could have consequences on the adequate identification of strategies to evaluate disturbance agents that are currently necessary to avoid local/regional extinction threats (Baigún, 2010).

The present study could, therefore, serve as a reference for decisions regarding the protection of this resource, by contributing to generating basic knowledge on the cryptic ichthyofauna present off the Colima coast and the biodiversity associated with coral communities. The accelerated urban, industrial and port growth of this region has led to alterations of the coastal zone, which could be affecting fish communities, especially species associated with coral substrates (Chávez-Comparan, 2008; Liñán-Cabello *et al.*, 2008).

We hypothesized that the diverse physiographic/topographic attributes, as well as the abundance patterns of the benthic communities, and exposure levels to anthropogenic impacts, would be determining factors regarding CF biodiversity patterns. The spatio-temporal behavior of CF should reflect lower biodiversity in the La Boquita coral community, as a consequence of its high level of exposure to anthropogenic pressure. The existence of some CF could serve as a simple bioindicator of health conditions of coral reefs.

MATERIALS AND METHODS

The coral community of La Boquita (LB) is located within Bahía de Santiago, in Manzanillo, Colima (19°06'05"-19°06'32"N, 104°23'21"-104°24'00"W). This location presents coral patches covering 3,876 m² at depths of approximately 2.3 m from the surface. It is greatly exposed to anthropogenic activities due to being easily accessible and at low depth. It is also degraded continuously due to thermal and sedimentary inputs derived from its artificial connection with the Juluapan Lagoon. The most abundant coral genera in this area are *Pocillopora*, *Porites*, and *Pavona* (Liñán-Cabello *et al.*, 2008, 2016).

The coral community of Carrizales Bay (CA) is located 7 km to the northwest of La Boquita; it has a rugged and complex topography, and depths ranging between 1 and 12 m. Different substrate types ranging from sand and round pebbles to large rocks can be observed in this community. It is the most extensive and representative coral expanse in the region, with the same representative coral genera as in LB. CA is cataloged as a prioritized marine area (A27) by CONABIO due to its high biodiversity value (Arriaga-Cabrera *et al.*, 1998). There are two main environmental seasons during the year in the study area: summer-fall (SF), when there is no precipitation and the average sea surface temperature is 24.8°C; and a winter-spring rainy season (WS), when the surface temperature increases to 27.7°C and there is a high concentration of nutrients (Olivos-Ortiz *et al.*, 2008; Muñiz-Anguiano *et al.*, 2017). Additionally, each season is characterized by patterns of coastal currents; there is generally an influence of the temperate current during WS and influence of warm waters during SF (Galicia-Pérez *et al.*, 2008).

Two sampling stations were located at each coral community. Station B1 in LB corresponded to a coral patch near the mouth of the Juluapan Lagoon, with average depths of 0.75 m, and station B2 corresponded to a coral patch away from the lagoon, with average depths of 2.5 m. Station C1 in CA was located at the western side, whereas station C2 was located at the eastern side of the bay. The two stations were at 1-10 m depths, where the highest density of coral mounds and pavements was found (Fig. 1). A total of 16 surveys were carried out at each station during WS in 2014, and eight surveys were carried out during SF in 2014. Three 30×2 m transects spaced 3 m away from each other and parallel to the coast were traveled during each survey (180 m²/sampling stations).

The habitats within the cracks and coralline structure were checked meticulously during each transect. When a CF was located, it was anesthetized,

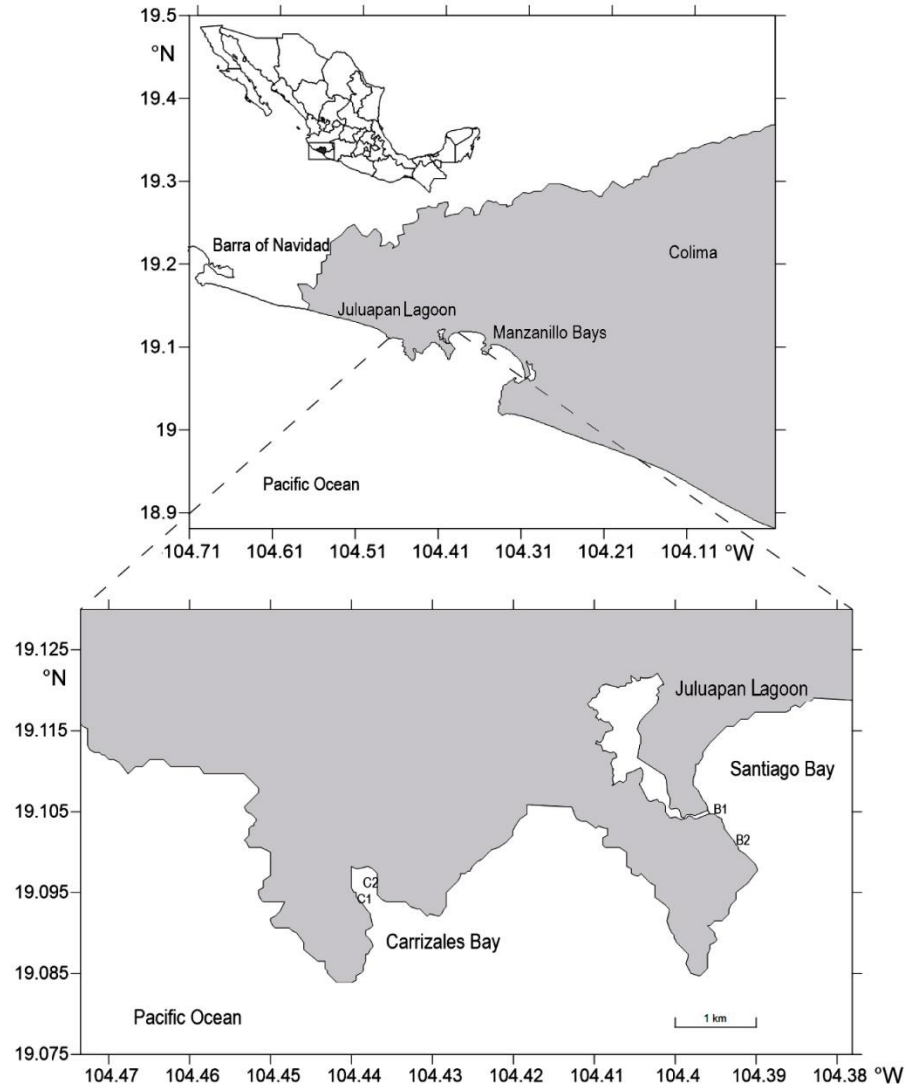


Figure 1. Location of the study area on the coast of Colima, Mexico. Sampling stations and influence area of the Juluapan Lagoon in the La Boquita Reef (B1 and B2), Carrizales Bay (C1 and C2).

using clove oil diluted in alcohol in a 1:3 proportion (García-Gómez *et al.*, 2011). This compound has an anesthetic effect in less than one minute; it was used *in situ* using a 300 mL atomizer. The anesthetized specimen was then collected to identify it using taxonomic keys by Allen & Robertson (1994), Castro-Aguirre *et al.* (1999), Thomson *et al.* (2000) and Robertson & Allen (2002). After this procedure and having identified signs of recovery, the specimen was freed at the collection site. The fish that could not be identified were collected using a 7×10 cm fishing net and fixed in 10% formaldehyde to be later identified in the laboratory. The criterion used for cataloging a species as cryptic is that it had cryptic habits during a stage of its life cycle (Balart *et al.*, 2006).

The video-transects were analyzed with the method used by Guzmán *et al.* (2004), which takes into account the convenience of studying dispersed coralline communities, at low depth, and with different topographic environmental conditions, such as those that exist on the east coast of the Pacific Ocean. Video-transects were obtained using a Sony 18 pxl camera held 60 cm above the marine bottom to characterize the substrate. Each video was analyzed, dividing the screen into 100 cells and estimating the percent cover of the biotic and abiotic substrate in each cell. This digital material was paused every 5 s to describe the CF community structure in coralline ecosystems. The relative abundance (RA) (Krebs, 1989), Shannon's diversity index (H) (Shannon & Weaver, 1963), the

frequency of occurrence, biological value index (BVI) (Loya-Salinas & Escofet, 1990), individual density, common species (C), rare species (R), exclusive species (E), and shared (S) species (Hill, 1973) were calculated.

A similarity matrix and cluster analyses were performed based on CF density to determine an affinity between stations and seasons. The analyses were carried out using Primer v6 software.

The composition, taken as the proportion of rocks (>128 mm), large sediments (particles 2-128 mm), and sand (<2 mm), was estimated based on the abiotic elements in each video analysis field (Pérez-Munguía & Pineda-López, 2005). Live and dead coral cover, as well as invertebrates and macroalgae cover, were estimated as part of the biotic elements.

Data analysis

After the normality and homoscedasticity tests were performed, one-way ANOVA tests were used to determine significant differences between stations, with 5% significance level. Benthic elements were taken as dependent variables, and sampling stations and species density were taken as independent variables. All tests were performed using Statistica v8 software. A principal components analysis (PCA) was carried out in order to determine temporal variability in CF abundance, as well as its relationship with the benthic elements of the studied coral communities. The analysis was carried out using Primer v6 software (Clarke & Gorley, 2006) with matrices built using the average cover of each benthic element and CF abundance at each coral community.

RESULTS

A total of 3,056 cryptic fish (CF) belonging to 23 species, 22 genera, 15 families, and six orders were identified in the two coral communities. The most represented families were the Pomacentridae and Chaenopsidae, with three species each. The families Muraenidae, Blenniidae, Gobiidae, and Labridae had two species each, and the families Synodontidae, Holocentridae, Cirrhitidae, Sciaenidae, Serranidae, Tripterygiidae, Tetraodontidae, and Diodontidae had one species each. There was also one record of the Syngnathidae family (*Hippocampus ingens*).

The species present in each community during the different seasons of the year are presented in Tables 1 and 2. Six CF species were recorded at stations B1 and B2 during winter-spring (WS): *Chromis limbaughi*, *Microspathodon dorsalis*, *Myripristis leiognathus*, *Stegastes rectifraenum*, *Synodus lacertinus*, and *Thalassoma lucasanum*. The following nine species

were recorded only at station B2: *Acanthemblemaria macrospilus*, *Bodianus diptotaenia*, *Canthigaster punctatissima*, *Coryphopterus urosphilus*, *Cirrhitichthys oxycechalus*, *Coralliozetus boehlkei*, *Diodon hystrix*, *Muraena lentiginosa*, and *Ophioblennius steindachneri*. At C1 and C2, 18 CF species were recorded during WS. *Gymnomuraena zebra* was recorded at C1 but not at C2, and *Pareques viola* was recorded at C2 but not at C1. During WS, the highest BVI values were obtained for *C. limbaughi* at B1, whereas at B2 the highest BVI values were obtained for *A. macrospilus* and *T. lucasanum* (Table 1).

Stations B1 and B2 had eight species in common during SF (*A. macrospilus*, *Axoclinus lucil*, *C. boehlkei*, *Ekmblemaria myersi*, *M. dorsalis*, *M. leiognathus*, *S. lacertinus*, and *T. lucasanum*); an additional nine species were present at B2. The highest BVI at stations B1 and B2 was obtained for *A. macrospilus* and *T. lucasanum*; however, the values of this index were higher at B2 (Tables 1-2).

Nineteen species occurred at stations C1 and C2; during WS, the two stations presented the same value of importance index. The highest density, dominance, and BVI value were obtained for *A. macrospilus*, *C. oxycechalus*, *M. dorsalis*, and *T. lucasanum* (Table 1).

Nineteen species occurred at station C1 and 18 species at station C2 during summer-fall (SF), with *Gymnomuraena zebra* being the only species not present at C2. The species with the highest degree of relative abundance, density, dominance, and BVI were *A. macrospilus*, *C. oxycechalus*, and *T. lucasanum* (Table 2).

The dominant species at station B1 during SF were *T. lucasanum* (0.13 ind m⁻²), *M. dorsalis* (0.06 ind m⁻²), *A. macrospilus* (0.11 ind m⁻²), and *C. boehlkei* (0.08 ind m⁻²). The last two species were not dominant during WS. The dominant species at station B2 during WS were *A. macrospilus*, *T. lucasanum*, and *C. boehlkei*. The dominant species at station C1 during WS were *C. oxycechalus* (0.29 ind m⁻², similar to the WS season), *A. macrospilus*, and *T. lucasanum*. The dominant species at C2 were similar to those found at C1 during WS. There were no rare species in the two coral communities.

Shannon's index presented values of 1.5 during WS and 1.75 during SF at station B1. This index was 2.5 during WS and SF at station B2, and this same value of 2.5 was obtained for C1 and C2 during the two studied seasons.

Station B1 showed the lowest species abundance, highest density, abundance, and BVI during the WS season. There were only three dominant species (*C. limbaughi*, *M. leiognathus*, and *T. lucasanum*) and three

Table 1. Ecological indices of cryptic fish in La Boquita (B) and Carrizales Bay (C) during the 2014 winter-spring period. RA: relative abundance, F: frequency, De: density (ind m⁻²), BVI: Biological Value Index. Species category of importance (CI), D: dominant, F: frequent, C: common, R: rare. Sampling stations: B1, B2, C1, C2. *Represents species that had not been reported on the coast of Colima.

Species	Sampling stations winter-spring															
	B1				B2				C1				C2			
	CI	RA	De	BVI	CI	RA	De	BVI	CI	RA	De	BVI	CI	RA	De	BVI
<i>Acanthemblemaria macrospilus</i> *		0.00	0.00		D	0.12	0.10	20.00	F	0.10	0.19	22.00	F	0.08	0.17	18.00
<i>Axoclinus lucillae</i> *		0.00	0.00			0.00	0.00			0.00	0.00			0.00	0.00	
<i>Bodianus diplotaenia</i>		0.00	0.00		F	0.04	0.03	8.00	F	0.03	0.07	12.00	F	0.04	0.08	12.00
<i>Canthigaster punctatissima</i>		0.00			F	0.03	0.03	6.00		0.02	0.04	6.00	F	0.02	0.04	8.00
<i>Chromis limbaughi</i>	D	0.40	0.42	10.00	F	0.09	0.08	16.00	F	0.03	0.07	12.00	F	0.04	0.09	14.00
<i>Cirrhitichthys oxycechalus</i>		0.00	0.00		F	0.08	0.07	14.00	D	0.15	0.28	24.00	D	0.12	0.24	22.00
<i>Coralliozetus boehlkei</i> *		0.00	0.00		D	0.10	0.09	18.00	F	0.03	0.05	10.00	F	0.02	0.04	8.00
<i>Coryphopterus urospilus</i>		0.00	0.00			0.05	0.04	10.00	F	0.03	0.07	12.00	F	0.04	0.09	14.00
<i>Diodon hystrix</i>		0.00	0.00		C	0.01	0.01	2.00	C	0.01	0.01	2.00	C	0.01	0.01	2.00
<i>Ekemblemaria myersi</i> *		0.00	0.00			0.00	0.00			0.00	0.00			0.00	0.00	
<i>Elacatinus punctulatus</i>		0.00	0.00			0.00	0.00		F	0.07	0.13	18.00	F	0.08	0.16	16.00
<i>Epinephelus labriformis</i>		0.00	0.00			0.00	0.00		F	0.02	0.03	4.00	F	0.01	0.02	4.00
<i>Gymnomuraena zebra</i>		0.00	0.00			0.00	0.00		C	0.01	0.01	2.00		0.00	0.00	
<i>Hippocampus ingens</i> *		0.00	0.00			0.00	0.00			0.00	0.00			0.00	0.00	
<i>Microspathodon dorsalis</i>	F	0.08	0.09	4.00	F	0.05	0.04	12.00	F	0.08	0.14	20.00	F	0.09	0.18	20.00
<i>Muraena lentiginosa</i>		0.00	0.00		F	0.01	0.01	4.00	C	0.01	0.01	2.00	C	0.01	0.01	2.00
<i>Myripristis leiognathus</i>	D	0.15	0.16	6.00	F	0.08	0.07	14.00	F	0.05	0.09	14.00	F	0.02	0.04	8.00
<i>Ophioblennius steindachneri</i>		0.00	0.00		F	0.04	0.03	8.00	F	0.06	0.11	16.00	F	0.04	0.09	14.00
<i>Pareques viola</i>		0.00	0.00			0.00	0.00			0.00	0.00		C	0.01	0.01	2.00
<i>Plagiotremus azaleus</i>		0.00	0.00			0.00	0.00		F	0.02	0.03	4.00	F	0.02	0.03	6.00
<i>Stegastes rectifraenum</i>	F	0.08	0.09	4.00	F	0.05	0.04	12.00	F	0.03	0.07	12.00	F	0.03	0.07	10.00
<i>Synodus lacertinus</i>	F	0.04	0.04	2.00	F	0.05	0.04	12.00	F	0.02	0.04	8.00	F	0.02	0.03	6.00
<i>Thalassoma lucasanum</i>	D	0.25	0.27	8.00	D	0.21	0.18	22.00	D	0.24	0.47	26.00	D	0.29	0.59	24.00

common species (*M. dorsalis*, *S. rectifraenum*, and *T. lucasanum*), which corresponds to a 1:1 relationship between the two levels of dominance. The other contrasts with what was observed during this same period for B2, C1, and C2, where proportions of 3:10:1, 1.66:4.3:1, and 1:7:1 of dominant: frequent: common species were obtained, respectively.

Station B1 also exhibited four dominant and four frequent species during SF; however, a change was observed in the presence of new dominant species: *A. macrospilus* and *C. boehlkei*, which in general did not show consistently high indices of relative abundance, density, and BVI, compared to what was observed during WS. It was observed that *T. lucasanum* was the only dominant species during all seasons and at all monitoring stations, presenting high densities, relative abundances, and BVI. Proportions at B2 were 3:12:1 during SF, which was very similar to what was observed during WS. Stations C1 and C2 had ratios of 1.5:7:1 and 1.5:6.5:1 respectively, which were very similar to what was observed during WS. It should be noted that the species of greatest dominance during the year at Carrizales reef were *A. macrospilus*, *C. oxycechalus*, and *T. lucasanum*. No rare species were recorded in the analyzed communities (Tables 1-2).

The cluster analysis based on CF density showed a similarity of approximately 50% between LB and CA

during WS and SF. There was a similarity of 85% between C1 and C2, and 60% between B1 and B2 (Fig. 2).

The similarity matrix showed the percent similarity between stations and between seasons (Table 3). There was 43.4% similarity between seasons at station B1, whereas there was 72.7% similarity between seasons at station B2. The similarity between seasons was 85% at station C1 and 82.1% at station C2. The CA stations were characterized by a similar abundance of CF between stations and seasons.

The video-transect analysis showed that during WS station B1 was represented mainly by rock (38.7%), sand, and coral (15.5%), of which 13.7% was live coral, 1.3% was dead coral, and 0.5% was coral fragments. The B2 station was mainly represented by coral (36%), of which 34% was live coral, 1.8% was dead coral, and 0.5% was coral fragments. There was 6% sponge cover at station B2 and a CF density of 0.9 ind m⁻². Coral cover was 69% at station C1 and 68% at station C2. There was 91.9% live coral, 5.7% dead coral, and 2.3% coral fragments at C1. There was 89% live coral, 6.2% dead coral, and 4.6% coral fragments at station C2. The presence of sponges was minimal at these two stations (0 and 1%, respectively). The CF density was similar at C1 and C2, with 1.91 ind m⁻² at station C1 and 2 ind m⁻² at station C2.

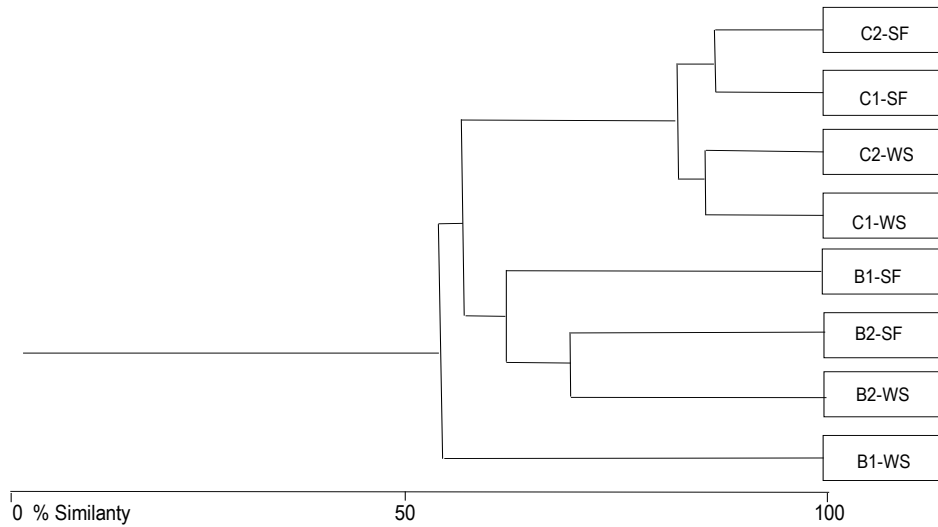


Figure 2. Cluster Analysis in relation to cryptic fish density for each station during the winter-spring (WS), summer-fall (SF) period and two reef communities (LB: La Boquita, CA: Carrizales Bay). Sampling stations: B1, B2, C1, C2.

Table 2. Ecological indices of cryptic fish in La Boquita (B) and Carrizales Bay (C) during the 2014 summer-fall period. RA: relative abundance, F: frequency, De: density (ind m⁻²), BVI: Biological Value Index. Species category of importance (CI), D: dominant, F: frequent, C: common, R: rare. Sampling stations: B1, B2, C1, C2. *Represents species that had not been reported on the coast of Colima.

Species	Sampling stations summer-fall															
	B1				B2				C1				C2			
	CI	RA	De	BVI	CI	RA	De	BVI	CI	RA	De	BVI	CI	RA	De	BVI
<i>Acanthemblemaria macrospilus</i> *	D	0.25	0.11	12.00	D	0.19	0.18	24.00	D	0.12	0.26	22.00	D	0.12	0.29	26.00
<i>Axoclinus lucillae</i> *	F	0.03	0.01	4.00	F	0.06	0.06	16.00	F	0.03	0.07	12.00	F	0.04	0.10	18.00
<i>Bodianus diplotaenia</i>		0.00	0.00		F	0.02	0.02	6.00	F	0.03	0.06	10.00	F	0.02	0.04	8.00
<i>Canthigaster punctatissima</i>		0.00	0.00		F	0.03	0.03	8.00	F	0.02	0.04	8.00	F	0.02	0.05	10.00
<i>Chromis limbaughi</i>		0.00	0.00		F	0.03	0.03	8.00	F	0.04	0.09	14.00	F	0.02	0.04	8.00
<i>Cirrhitichthys oxycechalus</i>		0.00	0.00		F	0.05	0.05	12.00	D	0.13	0.29	24.00	D	0.13	0.31	28.00
<i>Coralliozetus boehlkei</i> *	D	0.19	0.08	10.00	D	0.12	0.12	20.00	F	0.03	0.07	12.00	F	0.03	0.07	12.00
<i>Coryphopterus urospilus</i>		0.00	0.00			0.00	0.00		F	0.05	0.10	16.00	F	0.08	0.18	22.00
<i>Diodon hystrix</i>		0.00	0.00		C	0.01	0.01	2.00	C	0.01	0.01	2.00	C	0.00	0.01	2.00
<i>Ekemblemaria myersi</i> *	F	0.01	0.01	2.00	F	0.04	0.04	10.00		0.00	0.00			0.00	0.00	
<i>Elacatinus punctulatus</i>		0.00	0.00			0.00	0.00		F	0.08	0.18	20.00	F	0.08	0.20	24.00
<i>Epinephelus labriformis</i>		0.00	0.00		F	0.02	0.02	6.00	F	0.01	0.02	6.00	F	0.01	0.03	6.00
<i>Gymnomuraena zebra</i>		0.00	0.00			0.00	0.00		C	0.01	0.01	2.00		0.00	0.00	
<i>Hippocampus ingens</i> *		0.00	0.00		C	0.01	0.01	2.00		0.00	0.00			0.00	0.00	
<i>Microspathodon dorsalis</i>	D	0.14	0.06	8.00	F	0.06	0.06	16.00	F	0.04	0.09	14.00	F	0.06	0.13	18.00
<i>Muraena lentiginosa</i>		0.00	0.00			0.00	0.00			0.00	0.00			0.00	0.00	
<i>Myripristis leiognathus</i>	F	0.06	0.03	6.00	F	0.07	0.07	18.00	F	0.01	0.02	4.00	C	0.01	0.02	4.00
<i>Ophioblennius steindachneri</i>		0.00	0.00		F	0.06	0.06	14.00	F	0.07	0.16	18.00	F	0.07	0.17	20.00
<i>Pareques viola</i>		0.00	0.00			0.00	0.00			0.00	0.00			0.00	0.00	
<i>Plagiotremus azaleus</i>		0.00	0.00		F	0.02	0.02	4.00	F	0.02	0.04	8.00	F	0.01	0.03	6.00
<i>Stegastes rectifraenum</i>		0.00	0.00			0.00	0.00		F	0.03	0.07	12.00	F	0.03	0.08	14.00
<i>Synodus lacertinus</i>	F	0.03	0.01	4.00	F	0.02	0.02	4.00	F	0.03	0.07	12.00	F	0.02	0.04	8.00
<i>Thalassoma lucasanum</i>	D	0.29	0.13	14.00	D	0.18	0.17	22.00	D	0.26	0.58	26.00	D	0.23	0.54	30.00

There was 13.1% coral cover at station B1 in SF, of which 24% was dead coral. There was 29% coral cover at station B2, of which 15% was dead coral. There was no significant difference in sponge cover, but there was a difference in the species found during the two sampled seasons. There was a decrease in sea urchin abundance near SF. There were no great changes in benthic heterogeneity at C1 and C2, but there were differences in the proportion of dead coral.

The PCA relating CF abundance to benthic habitat characteristics showed that components 1 and 2 explained 87.2% of the variation (Table 4), with the first component separating the CA stations from the LB stations. Elements such as coral cover, sea urchin presence, depth, and CF abundance were important at CA stations. Rock cover, sediment and sand cover, as well as sponge and algae cover, were dominant at LB stations. The second principal component separated the

Table 3. The matrix of similarity between stations during the winter-spring (WS) and summer-fall (SF) periods. The asterisk (*) denotes similarity higher than 80%. Sampling stations: B1, B2, C1, C2.

	Similarity matrix							
	B1-WS	B2-WS	C1-WS	C2-WS	B1-SF	B2- SF	C1- SF	C2- SF
B1-WS	-	55.78	31.82	29.82	43.429	39.5522	25.5578	21.5385
B2-WS	-	-	58.52	54.76	60.684	72.7829	50.7246	46.9775
C1-WS	-	-	-	89.49 (*)	33.097	54.6512	85.0202 (*)	82.8125 (*)
C2-WS	-	-	-	-	31.435	50.3759	86.9221 (*)	82.1429 (*)
B1-SF	-	-	-	-	-	62.9482	30.6723	29.8211
B2-SF	-	-	-	-	-	-	51.3181	49.6644
C1-SF	-	-	-	-	-	-	-	90.8648 (*)
C2-SF	-	-	-	-	-	-	-	-

WS from the SF seasons. WS was characterized by greater sand and live coral cover, whereas SF had in addition to those substrate types, the dominance of sponges, sea urchins, algae, dead coral and coral fragments, as well as higher sediment cover, and greater CF abundance (Table 4, Fig. 3).

The PCA of CF and sampled stations showed that components 1 and 2 explained 72.3% of the variation. The first component separated the CF species associated with CA stations from those associated with LB stations. The species associated with CA stations were species 1, 2, 3, 4, 6, 8, 9, 11, 12, 13, 15, 16, 18, 19, 20, 21, 22, and 23, which showed an affinity for coral and sea urchin presence, and greater depth. The species associated with LB stations were species 5, 7, 10, 14, and 17, which showed an affinity for rock, sediment, algae, and sponge cover. The second component separated the species associated with the two seasons. The species associated with the WS period were species 3, 5, 6, 8, 11, 13, 15, 16, 17, 19, 20, 21, 22, and 23, which showed an affinity towards live coral and sand. The species associated with the SF period were species 1, 2, 4, 7, 9, 10, 12, 14, 18, and 20, which showed an affinity towards the presence of sponges, sea urchins, algae, dead and fragmented coral, and greater sediment cover (Table 4, Fig. 3).

DISCUSSION

There is currently some controversy regarding the characterization of cryptic fish, as some species are readily observed in their adult stage (*S. rectifraenum*), or are species with high camouflage ability but of relatively large size and therefore easily identified (*O. steindachneri*), or species with cryptic nocturnal habits

such as *T. lucasanum*. To designate a species as cryptic fish is not a division as such, and the definition is still ambiguous. This close relationship with the substrate can also contribute to considering them potential bioindicators of the studied reef systems. These specimens can be one of the most important components of reefs, as over 50% of species associated with reef systems are cryptic (Allen *et al.*, 1992; Thomson *et al.*, 2000).

According to some researchers, one of the main variables to consider in the study of CF is their behavioral patterns (Allen *et al.*, 1992; Thomson *et al.*, 2000); however, knowledge of ecological factors is extremely relevant. The ecological indicators allowed the identification of areas with the greatest CF richness and abundance. The CA stations had high richness values, with a maximum of 19 species. The LB stations had low species richness values. The dominant species at station B1 during WS were *C. limbaughi*, *M. leiognathus*, and *T. lucasanum*. The first two species are generalists and are associated with sandy/rocky environments. The dominant species at B2 were *A. macrospilus*, *C. boehlkei*, and *T. lucasanum* different from what was found at CA, where the dominant species were *C. oxyechalus* and *T. lucasanum*. The former inhabits exclusively coral branches, without evidence of eroding activity. This species was rarely observed at LB.

T. lucasanum was identified as a cryptic species by Balart *et al.* (2006). It has cryptic nocturnal habits and was dominant at all stations in LB as well as CA during both seasons, so that it stands out as a highly plastic species regarding habitat selection, which coincides with what has been reported by González-Cabello (2003), Zayas-Álvarez (2005), Galván-Villa (2008) and Domínguez-Domínguez *et al.* (2014), who described

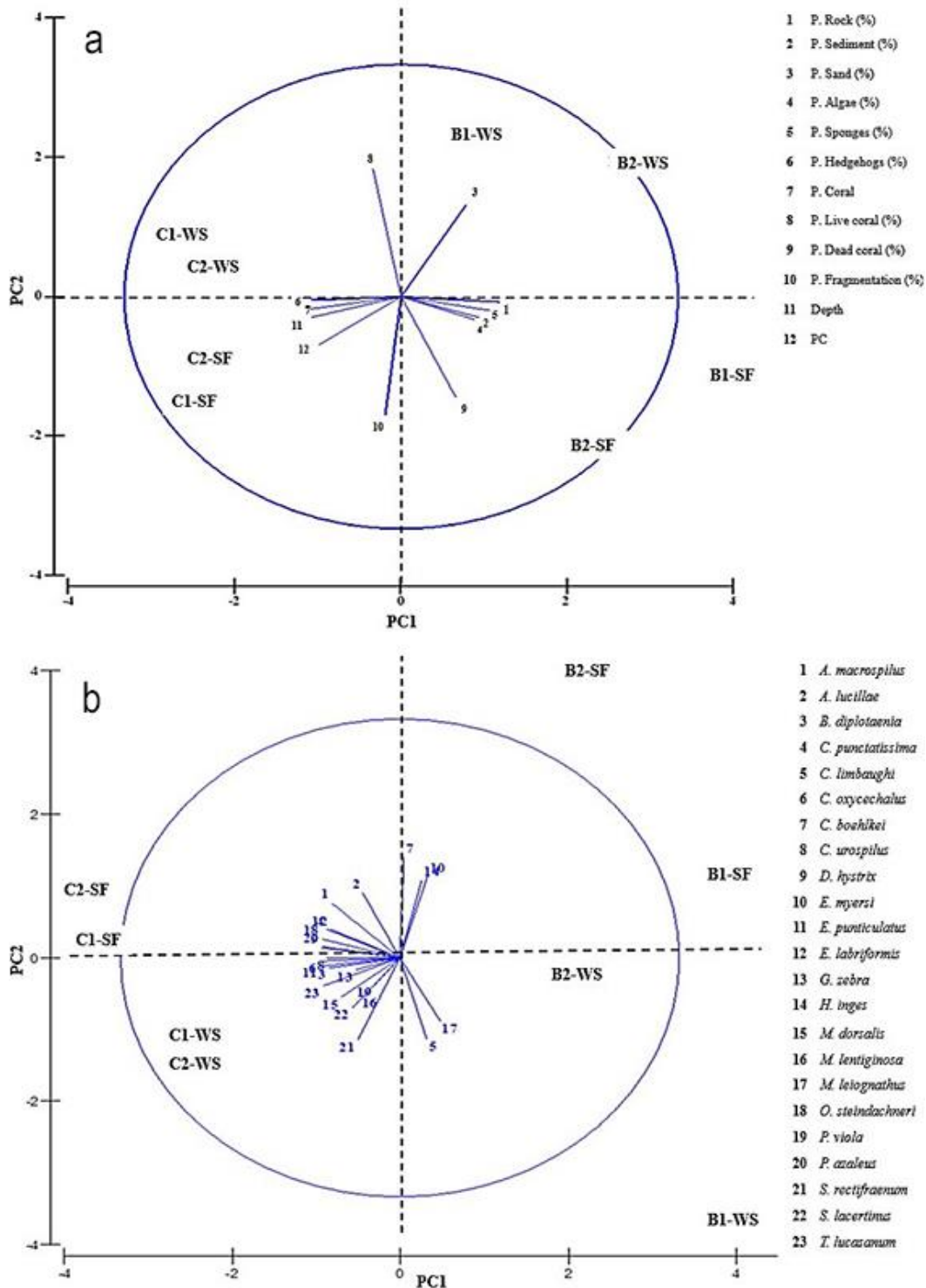


Figure 3. Main components relating elements of the benthic habitat to cryptic fish abundance. a) Association between benthic elements and each station and sampling period, b) association between cryptic fish abundance and each station and sampling period.

this species as dominant over the entire Mexican Pacific. Additionally, two modes of reproduction have been detected in this species. Some organisms,

including males and females, have a color phase with red and yellow side stripes and reproduce by egg dispersal. This type of reproduction is most commonly

Table 4. Principal components analysis. A) Relationship between benthic elements and sampled stations, B) relationship between cryptic fish abundance and sampled stations.

Graphs	PC	Self-values	Variation (%)	Cumulative variation (%)
A	1	7.7	64.2	64.2
	2	2.76	23	87.2
B	1	11.7	50.9	50.9
	2	4.92	21.4	72.3

observed in the summer. From this modality fish change to male and this change is called "terminal male." This male reproduces by forming a harem and spawning with females that are individually selected. Usually, this species has a terminal, sexually mature male that is removed and is soon replaced by a female newly transformed into a terminal male (Hernández-Olalde, 2008). This species feeds on crustaceans, algae, roe of other fish, and urchins (Eschmeyer & Herald, 1999). This reproductive and nutritional strategy could contribute to explain the dominance and plasticity of this species in the study site.

Few studies have tried to elucidate the temporal pattern of cryptic associations (Romero-Ponce, 2002; González-Cabello, 2003; Zayas-Álvarez, 2005). In the present study, the highest species richness (19 spp.) was observed during SF at all stations. According to the PCA, the species associated with the WS had a different profile than those observed during SF. Previous studies conducted during 2012 in the study region showed marked differences in the current surface temperatures between the two monitoring periods considered in this study. In the case of LB, average values of 24.8°C and 30.25°C were recorded during WS and SF, respectively, whereas in CA averages were 24.8°C and 29.35°C, for WS and SF, respectively (Muñiz-Anguiano *et al.*, 2017). Romero-Ponce (2002) recorded the greatest CF density in June and December in the Gulf of California, associated with a temperature increase. This author mentioned a possible relationship between the warm season and greater CF abundances. Zayas-Álvarez (2005) also reported greater CF densities with temperature increases in artificial reefs, despite the author recognizing that determining seasonality for this type of organism was complicated, due to their small size and short life cycles, which can affect the temporality of intercommunity associations. González-Cabello (2003) considered that CF associations are influenced by habitat characteristics and not by temporal effects. These authors concluded that there is no formal thermo-dependence of CF, that is, the habitat characteristics of the marine environment are what mainly affect the propagation of these species.

It is important to mention that of the 23 species reported in the present study, 18 had been previously reported by Chávez-Comparán (2008), whereas the species *H. ingens*, *Axoclinus lucillae*, *C. boehlkei*, and *E. myersi* are considered new records for the region. The species *A. lucillae* was observed at all stations but only during SF. This species is difficult to recognize due to its size (<6 cm), its camouflage characteristics as it lies on rocks, and its high speed of movement, which makes its capture difficult. The maximum relative abundance that it showed at the sampled stations was below 0.6, categorizing it as a frequent species. This species has been reported by Romero-Ponce (2002) and Zayas-Álvarez (2005) in La Paz Bay, with a relative abundance of less than 0.11.

The species *A. macrospilus*, *C. boehlkei*, and *E. myersi* belong to the Chaenopsidae family, which includes small-sized species (<4 cm length) that commonly inhabit polychaete tubes or empty mollusk shells. These species can be found on *Pocillopora* spp. coral substrates or on rocks; they lack scales, and the males tend to have a brighter coloration than the females (Torres-Hernández, 2011). The three species mentioned have been previously reported at other locations of the Central Mexican Pacific (González-Cabello, 2003; Galván-Villa *et al.*, 2010; Torres-Hernández, 2011; Domínguez-Domínguez *et al.*, 2014). In the present study, *A. macrospilus* was dominant at all stations mainly during SF, with the highest relative abundance at station B1 during SF.

The PCA analysis showed that compared to CA, where coral and rock cover dominated, the most representative substrates in LB were rocks with sedimentary deposits, the great abundance of sponges (mainly of the boring type), microalgae, and sandy bottoms. According to a study conducted by Liñan-Cabello *et al.* (2016) on the effects of terrestrial runoff in LB, the greatest impacts from sediments were observed during SF, characterized by greater precipitation in the region, seen mainly at station B1 due to its proximity to the Juluapan Lagoon, which led to greater thermal and osmotic instability as well as greater nutrient input. According to these authors, this influence has been strongly linked to an intense loss of coral cover from the substrate. According to a recent review by Brandl *et al.* (2018), habitat loss may be the most important threat to cryptobenthic fishes, and there is also evidence of small species with a high degree of habitat specialization being the first to succumb to changes (Wilson *et al.*, 2008; Brooker *et al.*, 2014; Brandl *et al.*, 2016). In in the La Boquita reef community, where organisms were exposed to greater environmental tension (SF), the higher density and abundance of 379 *A. macrospilus*, *C. boehlkei*, and *E. myersi* could be due to the fact that these species could

have the capacity, as proposed by Taylor & Van Tassel (2002), of presenting greater plasticity in micro-habitat use, which allows them to remain in the prevailing substrate.

Therefore, the increase in the density, abundance, and BVI of these species could be an indicator of a reef environment in a state of transition or degradation.

A study was undertaken by Galicia-Pérez *et al.* (2008) in our study area indicated that currents flow west to east during WS, which leads to the LB being isolated from discharge flows from Juluapan Lagoon. However, the circulation pattern is inverted during SF. According to records of sediment cover, there is a great impact due to an exchange of water masses over the coral community (Liñán-Cabello *et al.*, 2008, 2016). The effect of stress relatively isolates the coral population of CA due to sedimentary aggregation.

According to the results of the present study, the coral cover at the two CA stations was higher than at LB stations (36%) which could be a limiting factor for CF presence. Galván-Villa (2011) reported that heterogeneous communities provide more spaces for a greater variety of CF sizes, as they offer refugia from predators and can also reduce competition for space and food. With the present study, we confirm the previously stated argument by González-Cabello (2003) that greater coral cover has a positive effect on the richness and abundance of CF. According to our results, the greatest abundance and richness of species occurred at CA stations, not only because it is a coral community with a higher degree of conservation, but also due to the alternation between sandy and coral substrates, which increases the recruitment dynamics (Booth & Brosnan, 1995).

The ecological indicators allowed the evaluation of preferences for a given habitat type and recorded a degree of affinity towards specific habitat characteristics, which was observed in the abundance patterns recorded. Given the previously mentioned perturbation conditions of coral communities (Liñán-Cabello *et al.*, 2008, 2016; Muñiz-Anguiano *et al.*, 2017) it was possible to identify some species with bioindicator potential. According to the PCA, the dominant LB species belonged to the Chenopsideae family. In addition to being new records for the Colima coast, this family had the individuals with smallest sizes that were also characterized by inhabiting polychaete tubes, and it is possible that their abundance did not depend directly on coral abundance. Their affinity could explain their presence in LB towards the characteristics exhibited by this coral community.

On the other hand, the dominant species at CA stations were *A. macrospilus* and *C. oxycechalus*. The latter was recorded frequently at B2 and was absent

from B1. This species has potential as a bioindicator in relatively unperturbed crystalline waters, as it lives exclusively among coral branches, and is dominant on coral heads and frequent on rocky walls (González-Cabello, 2003; Zayas-Álvarez, 2005; Galván-Villa *et al.*, 2010). For this reason, the B1 conditions, which included a minimal coral cover, led to a lack of affinity of this species towards this site.

Coryphopterus urospilus was observed only at CA stations. This fish is associated with rocky and coral areas; it forages on small crustaceans among rocks, moving by resting its fins on the substrate, and its transparent coloration gives it greater camouflaging capacity (Allen & Robertson, 1998). However, there is little available information on the ecology of this species, which makes difficult explaining its absence from LB stations. Another important CF species was *E. punctulatus*, a small species (4 cm) that has been recorded in areas with massive corals. According to Allen & Robertson (1998), its abundance is associated with the sea urchin *Diadema mexicanum*. This CF species was observed at CA stations and was recorded as a frequent species during the two seasons. It shared its habitat with the previously mentioned sea urchin.

C. limbaughi was a dominant species at station B1, a planktivorous fish generally associated with coral environments where it feeds mainly on fish eggs (Schneider & Krupp, 1995), which could explain its dominance at B1, as its proximity to the Juluapan Lagoon could increase the abundance of zooplankton species (Pantaleón-López *et al.*, 2005).

Integrating the information from the present study, we can conclude that the physiographic and topographic characteristics of the marine substrate have an important effect on the occurrence of cryptic fish, especially of species with reduced movements. The CA coral community presented higher CF diversity, abundance, and richness than the LB reef community during the two sampled seasons. There was higher CF richness and diversity during the SF season. We identified *A. macrospilus*, *C. boehlkei*, and *E. myers* as being potential bioindicators of benthic habitat degradation. These species were associated with rocky environments with high sponge and macroalgae cover, whereas the species *C. oxycechalus*, *A. macrospilus*, *C. urospilus*, and *E. punctulatus* were associated with coralline, crystalline, and relatively unperturbed environments. The species *T. lucasanum* was identified as having high plasticity regarding habitat selection, as it was dominant at all stations and seasons sampled during the present study. In order to confirm our postulates regarding the preferences of fish for substrates and as bioindicator organisms, future investigations could consider the study of habitat preferences, ecophysiology, and adaptability of cryptic fish.

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