Species composition and bathymetric distribution of gorgonians (Anthozoa: Octocorallia) on the Southern Mexican Pacific coast

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Abstract: Composición de especies y distribución batimétrica de gorgonios (Anthozoa: Octocorallia) en la costa sur del Pacífico mexicano. Gorgonians are important components of coastal ecosystems, as they provide niches, natural compounds with medical applications and are used as bioindicators. Species composition and assemblage structure of gorgonians (Anthozoa: Octocorallia) were studied along a bathymetric profile in the Southern Mexican Pacific coast. Species composition was based on specimens collected within a depth range of 0-70m in 15 sites. The relative abundance of species was determined in six sites at four depths (5, 10, 20 and 25m) using three 10m^2 transects at each depth level. Twenty-seven species of gorgonians belonging to six genera and three families were registered. The species composition varied with depth: 11 species were distributed between 0-25m depth, while 17 species were found between 40-70m depth interval. The shallow zone is characterized by a relatively large abundance of gorgonians, dominated by colonies of *Leptogorgia cuspidata* and *L. ena.* In contrast, the deepest zone was characterized by relatively low abundance of gorgonians, dominated by *L. alba,* the only species observed in both depth intervals. The similarity analysis showed differences in the composition and abundance of species by depth and site, suggesting that the main factor in determining the assemblage structure is depth. Results of this study suggest that the highest richness of gorgonian species in the study area may be located at depths of 40-70m, whereas the highest abundances are found between 5 and 10m depth. This study represents a contribution to the poorly known eastern Pacific gorgonian biota. Rev. Biol. Trop. 61 (3): 1157-1166. Epub 2013 September 01.

Key words: abundance, bathymetrical distribution, diversity, gorgonians assemblages, Mexican Pacific.

Gorgonians are characteristic and abundant components of coastal benthic communities of the eastern Pacific waters (Breedy & Guzmán 2002). Due to their arborescent form, gorgonians increase spatial and ecological heterogeneity, providing niches for many associated species (Lasker 1985, Vreeland & Lasker 1989, Gerhardt 1990, Zea 1993). Some gorgonian species are significant sources of natural compounds used in biomedical research and pharmacology (McEnroe & Fenical 1978, Rodríguez & Ramírez 1994, Gutiérrez *et al.* 2004, 2005, 2006), and the presence and abundance of certain species has been shown to be beneficial to commercial fishing (Ruiz & Rada 2006). Gorgonians are also useful in environmental monitoring programs because various species are environmentally sensitive and can serve as bioindicators (Hernández-Muñoz *et al.* 2008).

Currently, efforts are underway to increase the body of knowledge of the richness of gorgonians in the Tropical eastern Pacific. Seven genera and four families have been reported in the shallow waters (Breedy & Guzmán 2003). Complete taxonomic reviews have been

undertaken for the genera *Pacifigorgia, Leptogorgia* and *Eugorgia* (Breedy & Guzmán 2002, 2007, 2009), and new species are being described (Breedy *et al*. 2012). Nevertheless, our understanding of the species composition and distribution of gorgonian assemblages remains limited.

Knowledge of the species diversity and distribution patterns of gorgonians in the Tropical eastern Pacific is so far limited to surveys from Costa Rica (Breedy 2009) and Panamá (Guzmán *et al.* 2004, 2008). For the Mexican Pacific coast, which is approximately 8 000km long with diverse oceanographic settings, there is a single work by Reyes-Bonilla *et al.* (1997), reporting 10 gorgonian species at Cabo Pulmo.

The purpose of this study is to identify the gorgonian species that inhabit the bathymetric range of 0-70m and characterize the relative abundance of gorgonian species along a 5-25m bathymetric profile on the Southern Pacific coast of Mexico.

MATERIALS AND METHODS

Study area: The study area is located in the Southern Mexican Pacific, along the coast of Oaxaca, between Puerto Escondido (15°52'10.48" N - 97°06'44.13" W) and Puerto Ángel (15°41'29.52" N - 96°14'13.38" W).

Fifteen sites were examined along 70km of coastline using SCUBA (Fig. 1). Bathymetric features, such as terraces and slope breaks, naturally divide the area into two types of sites: (1) adjacent to the coast, with a depth range from 0 to 25m, and (2) sites >100m from the coast, with a depth range from 40 to 70m. This division is likely related to the rate of sea level rise during the last 15 000 years and its effects on coastal erosion (Barrie & Conway 2002). All of the sites had rocky substratum, which is characteristic of the study area.

Taxonomy and species composition: To study the species composition, gorgonian colonies were identified *in situ* and collected for later validation. The census was conducted at 15 sites, nine sites were in the 0-25m depth range and six in the 40-70m depth range. Since the sampling effort may affect the final number of observed species, each site was visited the same number of times until no more species were recorded, resulting in a total of 10 visits per site.

The specimens were preserved by air-drying or fixed in 70% ethanol and identified

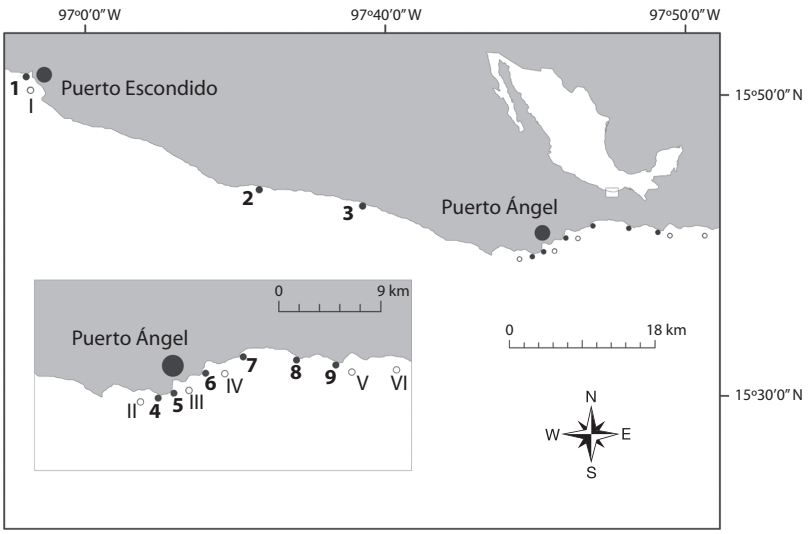

Fig. 1. Study area and location of sampling sites on the coast of Oaxaca, Mexico. Black points, 0-25m depth range: 1, 2, 3, 4, 5, 6, 7, 8, 9. White circles, 40-70m depth range: I, II, III, IV, V, VI.

through an analysis of the external morphology of the colony and the characteristics and composition of the sclerites following Bayer (1961) and Breedy & Guzmán (2002). A small fragment of each colony was placed in a hypochlorite sodium solution to separate the calcium carbonate sclerites from the organic material. Afterwards they were washed with water and examined under a light microscope (Olympus CX31). The specimens found were deposited in the Biological Collection of the Universidad del Mar, Oaxaca, Mexico, no. MHNUMAR-002B-01 - MHNUMAR-002B-27.

Gorgonian assemblages in relation to depth (5-25m) and sites: The species composition and relative abundance of gorgonians was determined for six of the nine sites in the 5-25m depth range (4, 5, 6, 7, 8 and 9). Stratified random sampling was conducted in each of the six study sites. Sampling was carried out along three 10m line transects at four depths (5, 10, 20 and 25m). These transects were marked with a 10m plastic tape to indicate ten consecutive $1m^2$ quadrats, which formed a total area of $10m^2$ for each transect. All gorgonians within each quadrat were identified and counted.

For the assemblage structure analysis, the original data were log(x+1) transformed to down-weight the contributions of dominant species relative to less common species (Clarke & Green 1988) and a Bray-Curtis dissimilarity matrix was constructed (Clarke *et al.* 2006). A two-way crossed similarity analysis (ANOSIM) with replicates was used to discover differences in the assemblage structures of gorgonians at different depths (5, 10, 20 and 25m) and among sites.

An analysis of similarity percentage (SIMPER) was used to identify the species responsible for major differences between depth groups. Analyses were performed with the program PRIMER 6 (Clarke 1993).

RESULTS

Taxonomy and species composition: In total, 27 gorgonian species belonging to six genera and three families were found, although six species require confirmation (Table 1).

The composition of gorgonians varied with depth. Of the 27 species observed, 11 were found within the 0-25m depth interval (Table 2) and 17 were found in the 40-70m depth interval (Table 3). *Leptogorgia alba* was the only species observed in both depth intervals.

TABLE 1
Systematic list of gorgonian species that occur in the south Pacific coast of Mexico

Subclass Octocorallia Haeckel, 1866
Order Alcyonacea
Suborder Holaxonia
Family Gorgoniidae Lamouroux, 1812
Eugorgia Verrill, 1868
Eugorgia daniana Verrill, 1868
Eugorgia excelsa Verrill, 1870
Eugorgia rubens Verrill, 1868
Eugorgia multifida Verrill, 1870
Eugorgia sp. 1

Leptogorgia Milne Edwards & Haime, 1857
Leptogorgia alba (Duchassaing & Michelotti, 1864)
Leptogorgia cuspidata Verrill, 1865
Leptogorgia exigua Verrill, 1870
Leptogorgia laxa Hickson, 1928
Leptogorgia ramulus (Milne Edwards & Haime, 1857)
Leptogorgia regis Hickson, 1928
Leptogorgia rigida Verrill, 1864
Leptogorgia ena Breedy, Abeytia & Guzmán 2012

Pacifigorgia Bayer, 1951
Pacifigorgia adamsii (Verrill, 1868)
Pacifigorgia englemanni (Horn, 1860)
Pacifigorgia media (Verrill, 1864)
Pacifigorgia rutila (Verrill, 1868)
Pacifigorgia senta Breedy & Guzmán, 2003
Pacifigorgia stenobrochis (Valennciennes, 1846)

Family Plexauridae Gray, 1859
Muricea austera Verrill, 1869
Muricea fruticosa Verrill, 1869

Psammogorgia Verrill, 1868
Psammogorgia sp. 1
Psammogorgia sp. 2
Psammogorgia sp. 3
Psammogorgia sp. 4
Suborder Calcaxonia
Family Ellisellidae
Ellisella limbaughi Bayer, 1960

TABLE 2
Gorgonian observed at the 0-25m depth range sites

Specie	La Dona	Agua blanca	Guapinole	El Faro	Fuente A	Estacahuite	La Foca	Boquilla	Secretario
Muricea austera	*	*	*	*					*
Leptogorgia alba	*	*	*	*	*	*	*	*	*
L. cuspidata	*	*	*	*	*	*	*	*	*
L. exigua		*	*				*		
L. rigida				*	*	*	*	*	*
L. ena	*	*	*	*	*	*	*	*	*
Pacifigorgia adamsii		*	*						
P. englemanni		*	*						
P. media	*	*	*		*	*	*		
P. rutila	*	*	*	*			*	*	*
P. stenobrochis	*	*	*	*		*			

TABLE 3
Gorgonian observed at the 40-70m depth range sites

Specie	Punto de presión	La Blanca	Fuente B	Antena	Toba	Salche
Eugorgia daniana		*				*
E. excelsa	*					
E. rubens		*				*
E. multifida		*				
Eugorgia sp. 1		*				
Muricea fruticosa	*	*	*	*	*	*
Leptogorgia alba	*	*	*	*	*	*
L. fruticosa		*				
L. laxa		*				
L. ramulus		*				*
L. regis		*				
Pacifigorgia senta		*				
Psammorgorgia sp. 1		*				
Psammorgorgia sp. 2		*				
Psammorgorgia sp. 3					*	
Psammorgorgia sp. 4		*				
Ellicella limbaughi	*					

At the 0-25m depth, all species belonged to the genera *Leptogorgia* (n=5) and *Pacifigorgia* (n=5), with the exception of *Muricea austera.* Four species (*L. alba*, *L. cuspidata*, *L. ena* and *L. rigida*) were present in all sites at 0-25m. *Pacifigorgia adamsii* and *P. englemanni* were only found in Guapinole and Agua Blanca, the two sites with the greatest species richness (n=10) (Table 1).

The species in the 40-70m depth interval included seven genera. *Leptogorgia* had the highest number of species (n=6), whereas only one species was found for *Pacifigorgia* and *Muricea*. All species belonging to the genera *Eugorgia* (n=5) or *Psammogorgia* (n=4) were found in deeper waters. Only *L. alba* and *M. fruticosa* were present in all sites. Fifty percent of the species found in the 40-70m depth interval

(n=9) were observed only in La Blanca, which was the site with the greatest species richness (n=15; Table 3). *E. excelsa* and *Psammogorgia* sp3 were each only found in one site (Punto de Presión and Toba, respectively; Table 3).

Assemblage structure in relation to depth (5-25m) and sites: Eight species were registered in the six shallow sites selected for this analysis. *L. cuspidata*, *L. ena* and *L. alba* were observed in all six sites, but only *L. alba* was found at all depths (Table 4).

The similarity analysis (ANOSIM) showed differences in the composition and abundance of species by depth (R global=0.68, p<0.1%) and site (R global=0.32, p<0.1%), suggesting that the main factor in determining the assemblage structure is depth.

The ANOSIM pair wise comparisons with depth as a factor showed that the least similarity was found between the shallowest and the deepest groups (5 and 25m; R=0.97, p<0.1%). The most similarity was found between the closest depths, both at the deeper (20 and 25m; R=0.40, p<0.2%) and shallower depth ranges (5 and 10m; R=0.64 p<0.1%). These findings suggest the existence of two main zones with the same composition but different relative abundance of gorgonian species: a shallow zone at 5-10m depth, and a deep zone at 20-25m depth. The shallow zone is characterized by a relatively large abundance

TABLE 4
Species composition and abundance of gorgonians by depth and sampling site

Site	Specie	5m	10m	20m	25m
Estacahuite	*L. cuspidata*	818	334	12	0
	L. ena	53	10	0	0
	L. rigida	65	32	0	0
	L. alba	17	35	156	101
Secretario	*L. cuspidata*	635	326	33	4
	L. ena	182	107	0	0
	L. rigida	53	37	0	0
	L. alba	3	28	106	179
	P. stenobrochis	0	0	0	1
El Faro	*L. cuspidata*	1083	589	141	19
	L. ena	367	338	29	0
	L. rigida	26	57	13	3
	L. alba	6	63	264	214
	P. stenobrochis	0	0	1	1
	P. rutila	0	0	2	1
Boquilla	*L. cuspidata*	814	732	140	8
	L. ena	956	318	28	0
	L. rigida	37	43	21	0
	L. alba	12	40	226	121
	P. rutila	0	0	2	0
Fuente	*L. cuspidata*	751	323	19	0
	L. ena	788	179	2	0
	L. rigida	51	36	8	0
	L. alba	5	33	170	96
	M. austera	1	0	0	0
Foca	*L. cuspidata*	807	827	104	14
	L. ena	66	29	15	3
	L. rigida	45	36	23	9
	L. alba	8	51	187	177
	L. exigua	1	0	0	0
	M. austera	0	2	0	0

of gorgonians, dominated by colonies of *L. cuspidata* and *L. ena.* In contrast, the deepest zone was characterized by relatively low abundance of gorgonians, dominated by *L. alba* (Fig. 2).

The species that contributed the most to the dissimilarity (SIMPER analysis) between the two levels of shallow strata (5 and 10m) were *L. cuspidata* (49.0%), *L. ena* (43.3%), *L. alba* (4.5%) and *L. rigida* (3.4%); and the species that contributed the most to the dissimilarity between 20 and 25m assemblage were *L. alba* (60%), *L. cuspidata* (30.0%), *L. rigida* (5.4%) and *L. ena* (4.3%).

DISCUSSION

Taxonomy and species composition: The gorgonian fauna along the study area is species-rich, with 27 species found compared to the 10 species recorded in the Gulf of California, Mexico (Reyes-Bonilla *et al.* 1997). However, further studies across the Mexican Pacific coast, including a wider bathymetric range, are required to achieve a complete inventory of species richness.

The gorgonian species richness in the present study area is similar to that of gorgonian

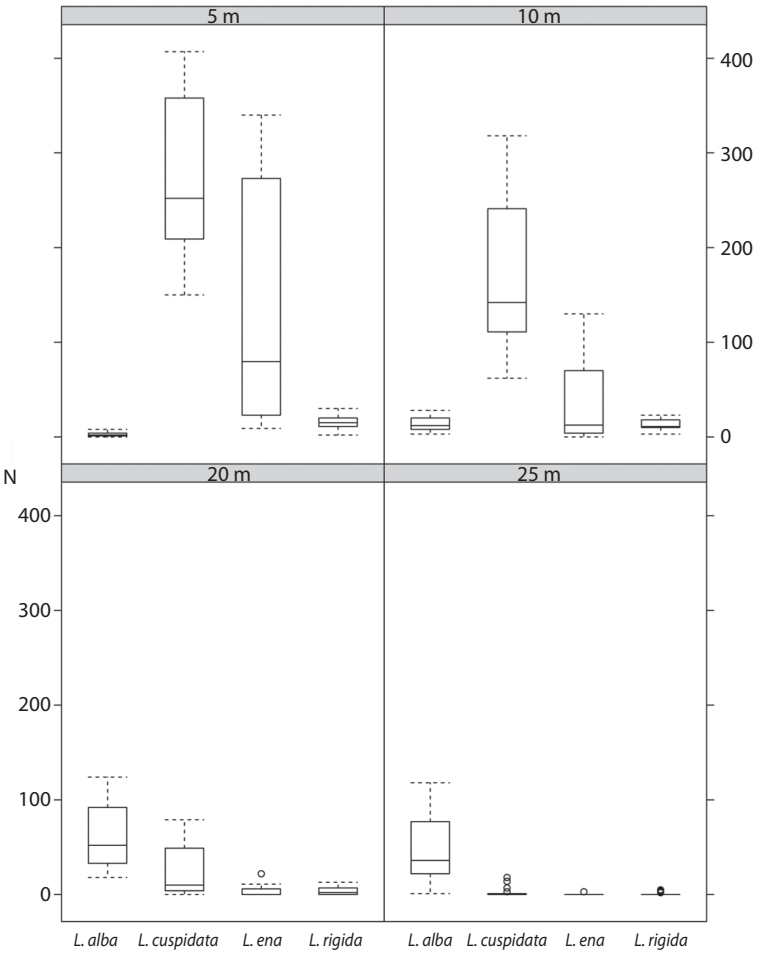

Fig. 2. Abundance of species at 5, 10, 20 and 25m depth in all sampling sites.

communities in other areas of the Tropical eastern Pacific. Thirty species have been reported in Costa Rica (Breedy & Guzmán 2003, Breedy & Cortés 2008, Breedy 2009), 34 and 38 species respectively have been reported in the Gulfs of Chiriquí and Panamá (Las Perlas Archipelago) in Panamá (Guzmán *et al*. 2004, 2008) and 25 species have been reported in the Colombian Pacific (Prahl *et al.* 1987). Gorgonian species richness in the study area was higher than the one reported for some other regions of the Tropical eastern Pacific: 11 species in El Salvador, 7 in Nicaragua and 13 in Perú (Breedy & Guzmán 2003, 2007, 2009).

Gorgonian species reported in this study represent new records for the Pacific coast of México. Twenty five out of 27 species were documented in Oaxaca for the first time (the only exceptions are *Eugorgia rubens* and *Eugorgia daniana*). *Leptogorgia ramulus, Leptogorgia regis* and *Ellisella limbaughi* constitute new records for México. All other species reported here were previously documented as Mexican Pacific gorgonian fauna (Reyes-Bonilla *et al*. 1997, Breedy & Guzmán 2003, 2007, 2009).

Leptogorgia alba was the only species that was found at all sampling sites and depths. This species is distributed all along the Tropical eastern Pacific coast and reportedly occurs around oceanic islands (e.g. Isla del Coco, Costa Rica and the Galapagos Islands, Ecuador; Breedy *et al.* 2009). However, in this study we documented a more extensive bathymetric range distribution than previously found for this species (Breedy & Cortés 2008), reaching 70m, giving *L. alba* the widest depth range of any gorgonian in the Tropical eastern Pacific.

At the 40-70m depth interval, six genera were identified and 66% of the species were observed, suggesting that deeper areas harbor more gorgonians species than shallow ones. This finding confirms other reports of a higher richness and abundance of gorgonian species at depths greater than 40m (Sánchez 1999, Ruiz & Rada 2006, Matsumoto *et al*. 2007, Rossi *et al*. 2008, Watanabe *et al*. 2009, Gori *et al*. 2010). This may be because shallow habitats are more severe due to water movement and competition with algae (Gori *et al*. 2011) compared with the relatively stable deeper environments.

In the 0-25m depth interval, the species composition was distributed more homogeneously among sites than in the deep strata (40-70m). This suggests a high level of ecological connectivity through superficial water circulation between sites, as has been reported for the Campeche Bank (Jordán-Dahlgren 2002), or by a long dispersal range of larvae. In contrast, at the deeper strata (40-70m), 61% of the species seem to be site specific, indicating limited connectivity between sites, which may be due to short dispersal range of the larvae and settlement near the parental colony, as has been observed in *Paramuricea clavata* (Coma *et al*. 1995, Linares *et al*. 2007). Studies of tropical reefs have documented the effect of variability in the dispersal capability of larvae on the resulting spatial structure of gorgonian assemblage (Jordán-Dahlgren 2002). Quantifying the effect of larval dispersal on gorgonian distribution on the Pacific coast of Mexico requires further study of larval biology, population biology, as well as the oceanographic processes in the study area.

Assemblage structure in relation to depth (5-25m) and sites: The main species that characterize the gorgonian assemblages at the 5-25m depth interval were *L. cuspidata*, *L. ena, L. alba* and *L. rigida*, because they were the most frequent and abundant species in all sampling sites. These assemblages with few species may be due to high environmental severity conditions of the study area related to high wave regime (Young 1999, Chen *et al*. 2002), high turbidity and sedimentation by river discharge (Glynn & Leyte-Morales 1997, Granja-Fernández & López-Pérez 2008) that may limit the presence of many species.

The main four gorgonian species exhibit different spatial distribution patterns along the 5-25m bathymetric profile. *L. cuspidata* and *L. ena* define the shallower (5-10m) sites and *L. alba* the deeper (20-25m) sites. These bathymetrical distribution pattern is not directly

related to light because their tissues do not contain symbiotic algae (pers. observ.) as has been observed in all species reported for the Tropical eastern Pacific (Breedy & Guzmán 2003, 2007, 2009). According to Fabricius & De'ath (2008), gorgonians that do not have symbionts do not require light, but instead depend on the flow of water to bring phytoplankton and other suspended food particles to their tentacles. The study area is a region of upwelling so there is enough food available to maintain great abundance of gorgonians.

A number of previous studies have demonstrated that wave action is an important factor in determining the zoning patterns of gorgonians in shallow habitats (Kinzie 1973, Opresko 1973, Birkeland 1974, Dinesen 1983, Botero 1987, Yoshioka & Yoshioka 1989, Sánchez *et al*. 1998). The greatest abundance of *L. cuspidata* and *L. ena* were found at depths of 5 and 10m, suggesting that they are well suited to this specific environment, perhaps due to their ability to grip the substrate. Their strong grip helps the colonies avoid detachment by wave action, which is one of the most significant factors in gorgonian mortality (Grigg 1975, Yoshioka & Yoshioka 1991).

Leptogorgia alba was the only species present at all depths, but it was more conspicuous at the deeper areas. Its extensive distribution might be related to its tolerance to a wide range of environmental conditions, as has been observed for *Eunicella singularis* in the Mediterranean Sea (Gori *et al*. 2010). Its low abundance at 5 and 10m suggest that in this environment this species is less tolerant or efficient than *L. cuspidata* and *L. ena*. Several studies note that larvae may reach different depths and then not survive due to specific forms of competition (La Barre *et al*. 1986, Dai 1990).

Further studies of environmental or biological factors that affect the distribution and relative abundance of gorgonian species, like type of substrate, coverage of substrate, and sedimentation in the Tropical eastern Pacific, are required to explain the abundance and distribution patterns of gorgonians species at different sites and depths.

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RESUMEN

La composición de especies y estructura de la comunidad de gorgonáceos se determinó a lo largo de un perfil batimétrico en la costa suroeste del Pacífico Mexicano. La composición de especies se realizó a través de una revisión y recolecta de especímenes entre 0 y 70m de profundidad en 15 sitios de muestreo. La caracterización de la estructura de la comunidad se realizó en seis sitios, en los cuales se colocaron tres transectos de $10m^2$ cada uno a 5, 10, 20 y 25m de profundidad. Se encontraron 27 especies de gorgonáceos pertenecientes a seis géneros y tres familias; aunque seis especies requieren ser confirmadas. La mayor riqueza de especies se registró entre 40 y 70m. La estructura de la comunidad entre 5 y 25m de profundidad mostró la existencia de dos zonas con la misma composición de especies pero con diferente abundancia relativa: una somera entre 5 y 10m de profundidad, caracterizada por una mayor abundancia de gorgonáceos y dominado por colonias de *Leptogorgia cuspidata* y *Leptogorgia ena* y una zona profunda entre 20 y 25m de profundidad, caracterizada por una baja abundancia de gorgonáceos y dominada por colonias de *Leptogorgia alba*.

Palabras clave: abundancia, distribución batimétrica**,** gorgonáceos, diversidad, Pacífico mexicano.

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