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Structure of molluscan communities in shallow subtidal rocky bottoms of Acapulco, Mexico

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Abstract: The objective of this study was to determine the structure of molluscan communities in shallow subtidal rocky bottoms of Acapulco, Mexico. Thirteen samplings were performed at 8 stations in 2012 (seven samplings), 2014 (four), and 2015 (two). The collection of the mollusks in each station was done at a maximum depth of 5 m for 1 h by 3 divers. A total of 2086 specimens belonging to 89 species, 36 families, and 3 classes of mollusks were identified. Gastropoda was the most diverse and abundant group. Calyptreaidae, Columbellidae, and Muricidae had >5 species, but Pisaniidae, Conidae, Fasciolariidae, and Muricidae had ≥15% of relative abundance. Most species found in this study were recorded in the rocky intertidal zone, and 10 species were restricted to the rocky subtidal zone. The affinity in the composition of the species during 2012–2015 had a low similarity (25%), but we could differentiate natural and anthropogenic effects according to malacological composition. In addition, 46% of the species recorded in this study are commercial fishing resources. We concluded that the rocky subtidal malacological fauna of Acapulco is highly diverse (89 species), and it has remained similar in space and time during this study.

Key words: Mollusk fauna, species of commercial importance, hard bottom, Guerrero, Acapulco Bay, Pacific Ocean

1. Introduction

The Mexican Pacific coast has greater diversity of marine mollusks with 2567 species compared with a total of 2067 recorded together in the Gulf of Mexico and the Mexican Caribbean (Castillo-Rodríguez, 2014). However, most of the subtidal studies in the Mexican Pacific were carried out in soft bottoms (Martínez-Cordoba, 1996; Zamorano et al., 2007; Ríos-Jara et al., 2008, 2009; Zamorano and Hendrickx, 2011; Hendrickx et al., 2014; Esqueda-González et al., 2014; Kuk-Dzul and Díaz-Castañeda, 2016), while the malacological description of subtidal hard bottoms has been a more recent undertaking (González-Medina et al., 2006; Landa-Jaime et al., 2013).

Mexican Pacific mollusks are valuable since many of these species are used for human consumption (Ríos-Jara et al., 2001; Baqueiro-Cárdenas and Aldana-Arana, 2003; Flores-Garza et al., 2012b; Castro Mondragón et al., 2015) and have potential economic value (Torreblanca-Ramírez et al., 2014). In addition, *Saccostrea palmula* Carpenter, 1857 and *Crassostrea corteziensis* Hertlein, 1951 are cultivated due to their economic importance (Baqueiro-Cárdenas, 1984). On the other hand, the species of the family Conidae have been used for the production of pharmaceutical compounds (Zamora-Bustillos et al., 2014; Morales-González et al., 2015). In the area of environmental monitoring, some mollusks are being used as indicators of pollution (Baqueiro-Cárdenas et al., 2007; Páez-Osuna and Osuna-Martínez, 2011).

Rocky subtidal bottoms have a high environmental heterogeneity, regarding the type of substrate and mineral that forms the rocks (Wilson, 1987; Guidetti et al., 2004). These characteristics of rocky bottoms have led in some cases to maintaining a high diversity and biomass of invertebrates compared to sandy bottoms (Wenner et al., 1983; Taylor, 1998). However, this natural heterogeneity can be affected by human actions, such as the refill of piers or collocations of barriers with an artificial substrate.

In the particular case of the rocky coast of Guerrero, Mexico, most studies of mollusks have been conducted in the intertidal zone (Galeana-Rebolledo et al., 2012; Torreblanca-Ramírez et al., 2012, 2017; Cerros-Cornelio et al., 2017). Given the importance of mollusks in the Mexican

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Pacific, the objectives of this study are: i) to determine the composition of the species, relative frequency of occurrence, relative abundance, and ecological attributes of the subtidal mollusks of different rocky coastal bottoms of Acapulco, Guerrero; ii) to compare the presence of rocky intertidal species with subtidal rocky species in this area of study and determine the species of economic importance in this environment; iii) and to determine the affinity of the taxocenosis of mollusks in the subtidal environment of Acapulco, Guerrero.

2. Materials and methods

2.1. Sampling

During 2012, 2014, and 2015, 13 samplings were done at 8 stations. In 2012, mollusks were collected at 7 stations from November to December: Muelle, Tlacopanocha, Manzanillo, Parque la Reina, Majahua, Palmitas, and Enamorados. In 2014, organisms were collected at four stations during February and March: La Angosta, Muelle, Majahua and Manzanillo; and in 2015, they were only collected at two stations in January: Manzanillo and La Angosta (Figure 1). The sampling effort was similar at all stations, which consisted of collecting all the mollusks that were found at each station at a maximum depth of 5 m for 1 h by 3 divers. The collection of organisms was done with basic diving equipment and using diving gloves for the poisonous specimens, and sometimes using a spatula to extract organisms adhered to rocks. All collections were done during the hours of low tide and on new moon days since it is more complicated to monitor vagile fauna and the identification of mollusks (Terlizzi et al., 2003). The method used in this study is similar to the one used by fisheries named capture per unit of effort (CPUE) (Poot-Salazar et al., 2014).

The descriptions of the collection stations were based on Mottana et al. (1980), in the geological charts of the National Institute of Statistics, Geography, and Informatics (INEGI; Acapulco E14-11, 1:50,000), and in observations made in the field. Stations varied regarding substrate type and exposure to the waves (Table 1). The type of substrate was classified as follows: 1) rocky massifs are fixed structures, such as walls and cliffs; 2) blocks are loose rock of more than 50 cm in diameter, motionless or barely able to move due to the impact of the waves; 3) boulders are loose rocks less than 50 cm and greater than 8 cm in diameter, which can be easily moved by the impact of the waves; 4) gravel is loose rock no more than 8 cm in diameter. The exposure to the waves was classified as two

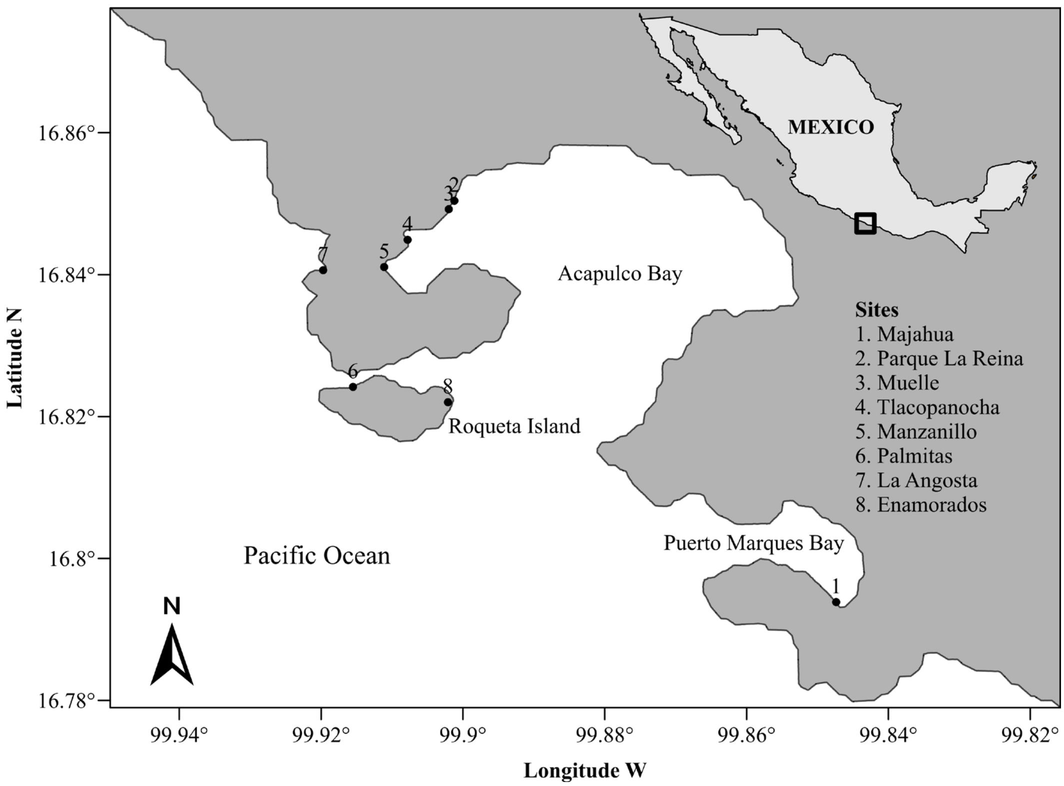

Figure 1. Stations sampled during 2012, 2014, and 2015 in Acapulco, Guerrero, Mexico.

Table 1. Environmental characteristics of sampling stations in the shallow subtidal environment of Acapulco, Mexico.

Station	Type of substrate	Type of rock	Exposure to the waves	Date of sampling
Majahua	Blocks and Boulders	Metamorphic	Sheltered	29-11-2012, 21-03-2014
Parque la Reina	Boulders and Gravel	Artificial substrates and igneous rocks	Sheltered	07-11-2012
Muelle	Blocks and Boulders	Metamorphic and artificial substrates	Sheltered	07-11-2012, 22-03-2014
Tlacopanocha	Boulders and Gravel	Artificial substrates and igneous rocks	Sheltered	23-11-2012
Manzanillo	Boulders and Gravel	Metamorphic and artificial substrates	Sheltered	21-11-2012, 22-03-2014, 09-01-2015
Palmitas	Massif rocks	Igneous rocks	Sheltered	08-12-2012
Enamorados	Massif rocks	Igneous rocks	Sheltered	09-12-2012
La Angosta	Massif rocks	Metamorphic	Exposed	26-02-2014, 09-12-2015

types, as sheltered or exposed; stations in the bays were classified as sheltered and only La Angosta was classified as exposed (Table 1).

The collected mollusks were kept in plastic bottles with 96% ethyl alcohol. The identification of the species was carried out using the keys of Keen (1971), Kaas and Van Belle (1985, 1994), Coan and Valentich-Scott (2012), and Tenorio et al. (2012). The 2019 WoRMS classification (http://www.marinespecies.org) was used for the nomenclature of species; if a species was not found in this database, Skoglund (2001) was used. The identified organisms were deposited in the collection of the Marine Ecology Faculty, Autonomous University of Guerrero.

2.2. Statistical analysis

Species richness (S) and abundance (ind. 3 divers^{-1} h^{-1}) were calculated. Species richness was considered as the total number of species per phylum, class, or family. Relative frequency of occurrence (RFO) was calculated by dividing the number of stations where the species were present by total numbers of stations and multiplying by 100. Relative abundance (RA) was calculated by dividing the number of individuals collected from each family by the total numbers of individuals and multiplying by 100.

Dominant species on a rank order were determined with the biological value index (BVI) according to Sanders (1960). This index considers the spatial and temporal abundance of the species, assigning scores in terms of the abundance of each sample and avoiding the ordination of the dominant species in each station but little representative (Loya and Escofet, 1990):

$$\mathrm{BVI}_i = \sum_{j=1} \mathrm{pu}_{ij}$$

where i corresponds to each species, j is the station of sampling, and pu_{ij} is the score of the species in sample i and sample j.

Cluster analysis was used to determine the spatial and temporal (all years) variability of mollusk species composition; this analysis was done with data of presence and absence of all species. The similarity of species composition among stations was determined using the Jaccard coefficient. The clusters of stations were constructed using the average of groups for all years (2012, 2014, and 2015). These analyses were done with the software PRIMER-E v6 (Clarke and Gorley, 2006).

3. Results

As shown in Table 2, most of the studies of the malacofauna in the Gulf of California and the Mexican Pacific coast have been conducted on subtidal soft bottoms and rocky intertidal, while very few studies have been done on subtidal hard bottoms. A total of 89 species of mollusks was identified in this study, 10 of polyplacophorans, 70 of gastropods, and 9 of bivalves (Table 2).

Thirty-seven families of mollusks were recorded, 5 of the Polyplacophora, 24 of the Gastropoda, and 8 of the Bivalvia. Families with more than 5 species were Calyptreaidae, Columbellidae, and Muricidae. On the other hand, families that had ≥15% relative abundance were Conidae, Fasciolariidae, Muricidae, and Pisaniidae (Figure 2).

Ten species of gastropods were restricted to the shallow subtidal rocky bottom in this study, belonging to the families Bursidae, Harpidae, Mitridae, Pinnidae, and Ranellidae (Table 3). In addition, a total of 41 species are economically important or with economic potential, which is equivalent to 46% of the total species recorded in the shallow subtidal, including two species of Polyplacophora (*Chiton articulatus* and *Chaetopleura lurida*), 5 species of Bivalvia, and 34 species of Gastropoda (Table 3).

A total of 2086 mollusk specimens were collected at eight stations. *Vasula speciosa* and *Cerithium atromarginatum* were found in the 8 stations sampled, while 7 species

Table 2. The number of species per mollusk class in different locations and habitats in the Gulf of California and the Mexican Pacific.

Locality	Habitat	Depth	Sampling method	Total species	References
Loreto Bay, Baja California Sur	Intertidal, subtidal rocky, subtidal soft bottom, red mangrove roots	<5m	Transect-quadrants	136 mollusks 4 polyplacophorans 61 bivalves 69 gastropods 2 cephalopods	Holguin-Quiñones et al., 2000
San Francisco Island, Baja California Sur	Subtidal soft bottom	---	---	109 mollusks 36 bivalves 44 gastropods 1 scaphopods	Tripp-Quezada et al., 2014
Santa Cruz Island, Baja California Sur	Subtidal soft bottom	3 m	Transect-quadrants	44 mollusks 25 bivalves 19 gastropods	Tripp-Quezada et al., 2018
Mazatlán Bay, Mexico	Sandy, rocky intertidal, shallow subtidal	3–10 m	Transect-quadrants, dredges, direct search	89 bivalves	Esqueda-González et al., 2014
Chamela Bay, Jalisco, Mexico	Rocky intertidal	0 m	Transect, drag, direct search	51 mollusks 3 polyplacophorans 6 bivalves 42 gastropods	Contreras et al., 1991
Tenacatita, Jalisco, Mexico	Coral reef, subtidal soft bottom, rocky intertidal	0 m	Direct search	123 mollusks 11 polyplacophorans 9 bivalves 87 gastropods	Landa-Jaime et al., 2013
Jalisco and Colima, Mexico	Subtidal soft bottom	20–80 m	Shrimp net	91 mollusks 12 bivalves 76 gastropods 3 cephalopods	Landa-Jaime and Arciniega-Flores, 1998
Coast Guerrero	Rocky intertidal	0 m	Quadrant	62 mollusks 3 polyplacophorans 9 bivalves 50 gastropods	Flores-Rodríguez et al., 2012
Troncones, Guerrero	Rocky intertidal	0 m	Quadrant	42 mollusks 1 polyplacophorans 8 bivalves 33 gastropods	Flores-Rodríguez et al., 2007
Roqueta Island, Acapulco, Guerrero	Rocky intertidal	0 m	Quadrant	44 mollusks 3 polyplacophorans 4 bivalves 34 gastropods	Valdés-González et al., 2004
Acapulco Bay, Guerrero	Rocky subtidal	<5 m	Direct search	89 mollusks 10 polyplacophorans 9 bivalves 70 gastropods	This study
Oaxaca, Mexico	Rocky intertidal	0 m	Quadrant	68 mollusks 11 polyplacophorans 8 bivalves 49 gastropods	Flores-Rodríguez et al., 2014
Gulf of Tehuantepec,	Rocky beach and rocky breakwaters Sandy subtidal	0 m 14–65 m	Direct search Shrimp trawl net	55 mollusks 22 bivalves 33 gastropods 58 mollusks 18 bivalves 40 gastropods	Ríos-Jara et al., 2009

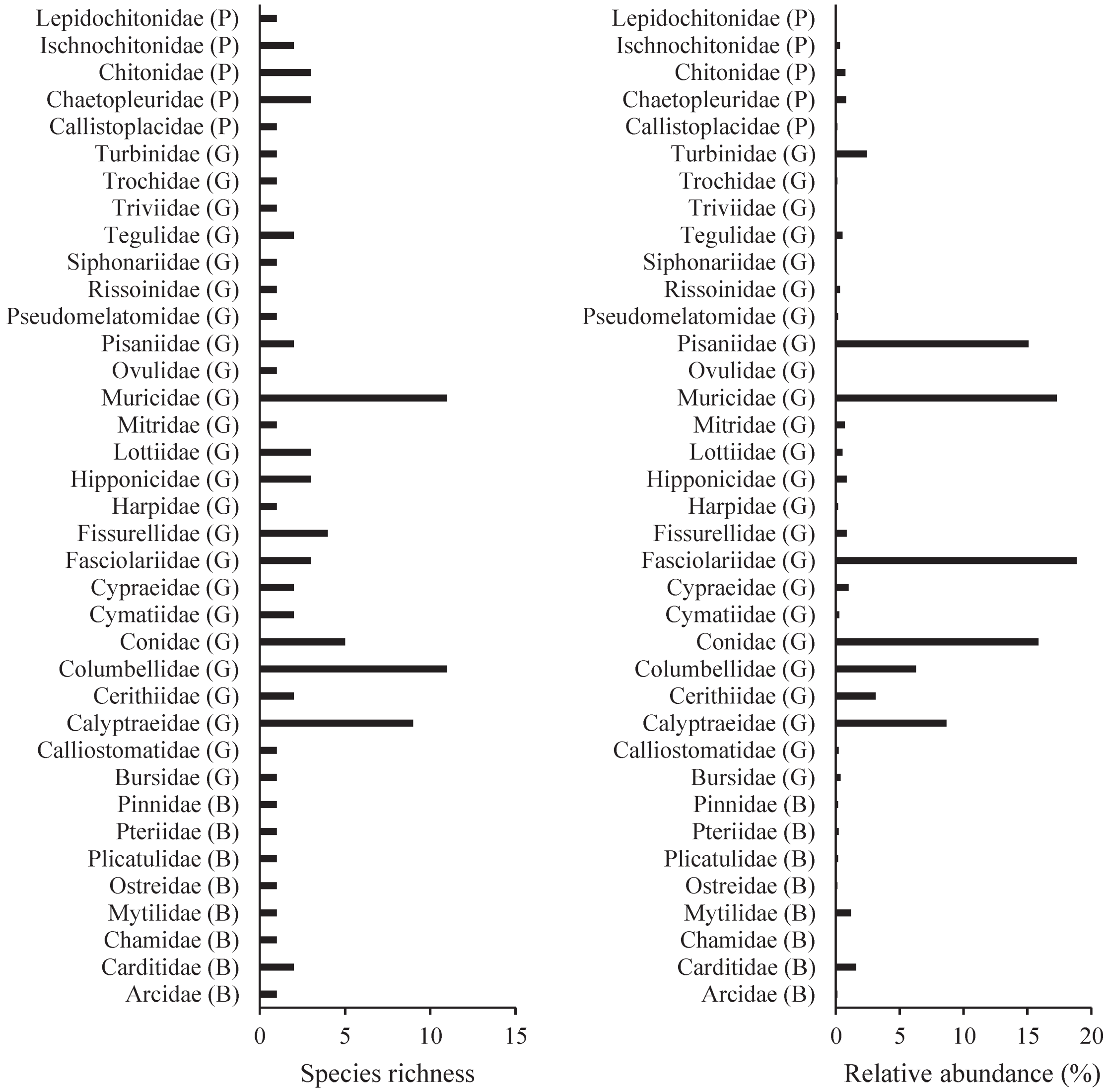

Figure 2. Species richness and relative abundance of families of mollusks in the subtidal zone of Acapulco, Mexico: Polyplacophora (P), Gastropoda (G), and Bivalvia (B).

were found in 7 stations, 3 species in 6 stations, 3 species in 5 stations, and 9 species in 4 stations (50% of stations). On the other hand, the most frequent species were not always the most abundant; for example, *Leucozonia cerata* had a higher relative abundance than *Vasula speciosa*, while *Conus nux*, *Geomophos sanguinolentus*, and *Conus gladiator* showed greater relative abundance than *Cerithium atromarginatum* (Table 4).

According to the BVI, which takes into account the frequency and abundance, it was possible to determine 15 dominant species in the shallow subtidal rocky environments (Figure 3), highlighting *Vasula speciosa* (261), *Leucozonia cerata* (231), *Conus nux* (224), *Gemophos sanguinolentus* (214), *Engina tabogaensis* (191), *Columbella major* (186), *Cerithium atromarginatum* (174), *Conus gladiator* (166), *Crucibulum umbrella* (159), *Conus princeps* (157), *Uvanilla unguis* (135), *Trachypollia lugubris* (128), *Opeatostoma pseudodon* (127), *Acanthais triangularis* (120), and *Pseudozonaria arabicula* (88).

According to the results of the faunal affinity, two groups were formed during the three years (2012–2015). The station of La Angosta in 2014 was separated from all the other stations; Muelle 2012 and La Angosta 2015 were clustered into Group 1; and all the other stations sampled

Table 3. Total abundance (n), presence in the rocky intertidal zone, and economic importance of mollusk species of the rocky subtidal zone in Acapulco Mexico according to different researchers. Names of species in bold means they are only recorded in the subtidal zone, and letters a–m indicate the studies in which the distributional and economical information of the species were given: Ríos-Jara et al., 2001[a]; Flores-Garza et al., 2012a[b], 2012b[c]; Galeana-Rebolledo et al., 2012[d]; Torreblanca-Ramírez et al., 2012[e]; Flores-Garza et al., 2014[f]; Torreblanca-Ramírez et al., 2014[g]; Castro-Mondragón et al., 2015[h]; Cerros-Cornelio et al., 2017[i]; López-Rojas et al., 2017[j]; Torreblanca-Ramírez et al., 2017[k]; Flores-Garza et al., 2018[l]; Galeana-Rebolledo et al., 2018[m].

Class/family	Species	n	Intertidal zone	Economic importance
POLYPLACOPHORA				
Callistoplacidae	*Callistoplax retusa* (Sowerby in Broderip & Sowerby, 1832)	3	e, d	
Chaetopleuridae	*Chaetopleura hanselmani* (Ferreira, 1982)	1	e	
Chaetopleuridae	*Chaetopleura lurida* (G. B. Sowerby I, 1832)	7	e, d	m
Chaetopleuridae	*Chaetopleura unilineata* Leloup, 1954	9	e, d	
Chitonidae	*Chiton albolineatus* Broderip & G. B. Sowerby I, 1829	13	e, d	
Chitonidae	*Chiton articulatus* Sowerby in Broderip & Sowerby 1832	2	e, d	c, m
Chitonidae	*Tonicia forbesii* Carpenter, 1857	1	e, d	
Ischnochitonidae	*Ischnochiton muscarius* (Reeve, 1847)	4	e, d	
Ischnochitonidae	*Stenoplax limaciformis* (Sowerby, 1832)	3	e, d	
Lepidochitonidae	*Cyanoplax hartwegii* (Carpenter, 1855)	1	b	
GASTROPODA				
Bursidae	***Bursa corrugata* (Perry, 1811)**	8		
Calliostomatidae	*Calliostoma aequisculptum* Carpenter, 1865	5	k	
Calyptraeidae	*Bostrycapulus aculeatus* (Gmelin, 1791)	7	k	
Calyptraeidae	*Crepidula excavata* (Broderip, 1834)	19	k	
Calyptraeidae	*Crepidula incurva* (Broderip, 1834)	7	e, k	g
Calyptraeidae	*Crepidula onyx* G. B. Sowerby I, 1824	10	k	
Calyptraeidae	*Crepidula striolata* Menke, 1851	4	k	
Calyptraeidae	***Crucibulum concameratum* Reeve, 1859**	42		
Calyptraeidae	*Crucibulum scutellatum* (Wood, 1828)	7	e, k	g, c
Calyptraeidae	*Crucibulum subactum* Berry, 1963	7	k	
Calyptraeidae	*Crucibulum umbrella* (Deshayes, 1830)	78	e, k	g, c
Cerithiidae	***Cerithium atromarginatum* Dautzenberg & Bouge, 1933**	64		
Cerithiidae	*Cerithium menkei* Carpenter, 1857	1	k	
Columbellidae	*Anachis guerreroensis* A. M. Strong & Hertlein, 1937	2	k	
Columbellidae	*Anachis nigrofusca* Carpenter, 1857	1	e	g
Columbellidae	*Anachis spadicea* (Philippi, 1846)	3	k	
Columbellidae	*Columbella fuscata* G. B. Sowerby I, 1832	10	e, k	g
Columbellidae	*Columbella major* G. B. Sowerby, 1832	87	e, k	g
Columbellidae	*Columbella sonsonatensis* (Mörch, 1860)	3	k	g
Columbellidae	*Cosmioconcha palmeri* (Dall, 1913)	1	k	g
Columbellidae	*Decipifus lyrta* (Baker, Hanna & A. M. Strong, 1938)	2	k	
Columbellidae	*Mitrella ocellata* (Gmelin, 1791)	1	e, k	g
Columbellidae	*Mitrella xenia* (Dall, 1919)	2	e, k	g
Columbellidae	*Parvanachis pygmaea* (G. B. Sowerby I, 1832)	19	e, k	
Conidae	*Conus brunneus* W. Wood, 1828	4	k	
Conidae	*Conus gladiator* Broderip, 1833	92	k	

Table 3. (Continued).

Conidae	*Conus nux* Broderip, 1833	186	k	g
Conidae	*Conus princeps* Linnaeus, 1758	46	k	a
Conidae	*Conus purpurascens* G. B. Sowerby I, 1833	3	k	a
Cymatiidae	*Monoplex vestitus* (Hinds, 1844)	5	k	
Cymatiidae	***Turritriton gibbosus* (Broderip, 1833)**	1		
Cypraeidae	*Macrocypraea cervinetta* (Kiener, 1844)	1	e, k	g
Cypraeidae	*Pseudozonaria arabicula* (Lamarck, 1810)	20	e, k	g
Fasciolariidae	*Leucozonia cerata* (W. Wood, 1828)	258	e, k	g, c
Fasciolariidae	*Opeatostoma pseudodon* (Burrow, 1815)	131	e, k	g, c
Fasciolariidae	***Pustulatirus mediamericanus* (Hertlein & A. M. Strong, 1951)**	4		
Fissurellidae	*Diodora inaequalis* (G. B. Sowerby I, 1835)	10	k, i	g
Fissurellidae	*Diodora saturnalis* (Carpenter, 1864)	4	k, i	
Fissurellidae	*Fissurella decemcostata* McLean, 1970	2	k, i	
Fissurellidae	*Fissurella gemmata* Menke, 1847	2	k, i	c
Harpidae	***Morum tuberculosum* (Reeve, 1842)**	4		
Hipponicidae	*Hipponix delicatus* Dall, 1908	1	k	g
Hipponicidae	*Hipponix panamensis* C. B. Adams, 1852	8	k	
Hipponicidae	*Pilosabia trigona* (Gmelin, 1791)	9	k	
Lottiidae	*Lottia mesoleuca* (Menke, 1851)	3	k	g
Lottiidae	*Lottia pediculus* (Philippi, 1846)	7	k	g
Lottiidae	*Lottia fascicularis* (Menke, 1851)	1	e	g
Mitridae	***Strigatella tristis* (Broderip, 1836)**	15		
Muricidae	*Acanthais triangularis* (Blainville, 1832)	46	k	
Muricidae	***Aspella pyramidalis* (Broderip, 1833)**	1		
Muricidae	*Favartia erosa* (Broderip, 1833)	3	l	
Muricidae	*Hexaplex princeps* (Broderip, 1833)	7	k	c, m
Muricidae	***Homalocantha oxyacantha* (Broderip, 1833)**	1		
Muricidae	*Vasula speciosa* (Valenciennes, 1832)	237	e	g, c
Muricidae	*Muricopsis zeteki* Hertlein & A. M. Strong, 1951	18	e	g
Muricidae	*Tripterotyphis fayae* (Keen & Campbell, 1964)	1	l	
Muricidae	*Stramonita biserialis* (Blainville, 1832)	4	e, k	g
Muricidae	*Trachypollia lugubris* (C. B. Adams, 1852)	38	e, k	g
Muricidae	*Vitularia salebrosa* (P. P. King, 1832)	5	k	
Ovulidae	*Jenneria pustulata* (Lightfoot, 1786)	1	e, k	g
Pisaniidae	*Engina tabogaensis* Bartsch, 1931	138	e, k	g
Pisaniidae	*Gemophos sanguinolentus* (Duclos, 1833)	177	k	
Pseudomelatomidae	*Pilsbryspira garciacubasi* Shasky, 1971	4	k	
Rissoinidae	*Rissoina stricta* (Menke, 1850)	7	k	g
Siphonariidae	*Siphonaria gigas* G. B. Sowerby I, 1825	2	k	
Tegulidae	*Tegula globulus* (Carpenter, 1857)	9	e, k	g
Tegulidae	*Tegula panamensis* (Philippi, 1849)	2	k	
Triviidae	*Niveria pacifica* (Sowerby, 1832)	1	k	
Trochidae	*Monilea patricia* (Philippi, 1851)	3	k	
Turbinidae	*Uvanilla unguis* (W. Wood, 1828)	51	k	h

Table 3. (Continued).

BIVALVIA				
Arcidae	*Arca mutabilis* (G. B. Sowerby I, 1833)	3	d, j	
Carditidae	*Carditamera affinis* (G. B. Sowerby I, 1833)	1	d, j, f	
Carditidae	*Cardites grayi* (Dall, 1903)	32	e, d, j, f	h
Chamidae	*Chama coralloides* Reeve, 1846	2	j, f	c, m
Mytilidae	*Modiolus capax* (Conrad, 1837)	25	e, d, j, f	c, m
Ostreidae	*Striostrea prismatica* (Gray, 1825)	3	j, f	h, m
Pinnidae	***Pinna rugosa* G. B. Sowerby I, 1835**	4		c
Plicatulidae	*Plicatula penicillata* Carpenter, 1857	4	d, j, f	
Pteriidae	*Pinctada mazatlanica* (Hanley, 1856)	5	j, f	c, m

Table 4. Relative frequency of occurrence (RFO) and relative abundance (RA) of mollusks in the rocky subtidal of Acapulco, Mexico. 1: Majahua, 2: Parque la Reina, 3: Muelle, 4: Tlacopanocha, 5: Manzanillo, 6: Palmitas, 7: La Angosta, 8: Enamorados.

Class/species	1	2	3	4	5	6	7	8	RFO (%)	RA (%)
POLYPLACOPHORA										
Callistoplax retusa			3						12.5	0.14
Chaetopleura hanselmani			1						12.5	0.05
Chaetopleura lurida	3				4				25	0.34
Chaetopleura unilineata			5				4		25	0.43
Chiton albolineatus			10				3		25	0.62
Chiton articulatus	1		1						25	0.1
Cyanoplax hartwegii					1				12.5	0.05
Ischnochiton muscarius							4		12.5	0.19
Stenoplax limaciformis							3		12.5	0.14
Tonicia forbesii			1						12.5	0.05
GASTROPODA										
Acanthais triangularis	1	22	1	4	9	5		4	87.5	2.21
Anachis guerreroensis					2				12.5	0.1
Anachis nigrofusca	1								12.5	0.05
Anachis spadicea					3				12.5	0.14
Aspella pyramidalis					1				12.5	0.05
Bostrycapulus aculeata					7				12.5	0.34
Bursa corrugata				1		7			25	0.38
Calliostoma aequisculptum				5					12.5	0.24
Cerithium atromarginatum	16	19	7	9	1	10	1	1	100	3.07
Cerithium menkei								1	12.5	0.05
Columbella fuscata	7	1	1	1					50	0.48
Columbella major	6	25	13	27	11			5	75	4.17
Columbella sonsonatensis				2	1				25	0.14
Conus brunneus				2				2	25	0.19
Conus gladiator	6	51	4	6	16	1		8	87.5	4.41
Conus nux	22		37	16	23	26	17	45	87.5	8.92
Conus princeps	10	3	4	3		9	1	16	87.5	2.21

Table 4. (Continued).

Conus purpurascens	3								12.5	0.14
Cosmioconcha palmeri					1				12.5	0.05
Crepidula excavata	1			1	17				37.5	0.91
Crepidula incurva					6		1		25	0.34
Crepidula onyx	2	5	1		2				50	0.48
Crepidula striolata	2	1			1				37.5	0.19
Crucibulum concameratum	4	1	31		6				50	2.01
Crucibulum scutellatum				1		6			25	0.34
Crucibulum subactum		2		1	4				37.5	0.34
Crucibulum umbrella	4		10	7	55	1		1	75	3.74
Decipifus lyrta		2							12.5	0.1
Diodora inaequalis		1	1	3	5				50	0.48
Diodora saturnalis					4				12.5	0.19
Engina tabogaensis	14	60		6	27	28	3		75	6.62
Favartia erosa					3				12.5	0.14
Fissurella decemcostata		1		1					25	0.1
Fissurella gemmata					1			1	25	0.1
Gemophos sanguinolentus	15	33	7	84	32	3		3	87.5	8.49
Hexaplex princeps	1	4				2			37.5	0.34
Hipponix delicatus					1				12.5	0.05
Hipponix panamensis					8				12.5	0.38
Homalocantha oxyacantha			1						12.5	0.05
Jenneria pustulata	1								12.5	0.05
Leucozonia cerata	7		79	24	29	26	6	87	87.5	12.37
Lottia fascicularis				1					12.5	0.05
Lottia mesoleuca					3				12.5	0.14
Lottia pediculus		5				1		1	37.5	0.34
Macrocypraea cervinetta					1				12.5	0.05
Mitrella ocellata					1				12.5	0.05
Mitrella xenia				1		1			25	0.1
Monilea patricia		1		1	1				37.5	0.14
Monoplex vestitus	1		1	2				1	50	0.24
Morum turberculosum	2			1	1				37.5	0.19
Muricopsis zeteki	4	8		5	1				50	0.86
Niveria pacifica								1	12.5	0.05
Opeatostoma pseudodon		43	5	3		36	4	40	75	6.28
Parvanachis pygmaea	8				11				25	0.91
Pilosabia trigona	6	2			1				37.5	0.43
Pilsbryspira garciacubasi		3		1					25	0.19
Pseudozonaria arabicula	3		5	9	1			2	62.5	0.96
Pustulatirus mediamericanus	3				1				25	0.19
Rissoina stricta	2	1	1		3				50	0.34
Siphonaria gigas								2	12.5	0.1
Stramonita biserialis				1	3				25	0.19

Table 4. (Continued).

Strigatella tristis	4	6		4	1				50	0.72
Tegula globulus	1				8				25	0.43
Tegula panamensis				1	1				25	0.1
Trachypollia lugubris	9		3		24	1		1	62.5	1.82
Tripterotyphis fayae					1				12.5	0.05
Turritrion gibbosus				1					12.5	0.05
Uvanilla unguis	12	14	1	9	4	8		3	87.5	2.44
Vasula speciosa	37	54	10	20	28	27	17	44	100	11.36
Vitularia salebrosa	2			1	2				37.5	0.24
BIVALVIA										
Arca mutabilis	3								12.5	0.14
Carditamera affinis		1							12.5	0.05
Cardites grayi	1		3	27		1			50	1.53
Chama coralloides					2				12.5	0.1
Modiolus capax	1			2	8	10		4	62.5	1.2
Pinctada mazatlanica	1			2	2				37.5	0.24
Pinna rugosa	1	2			1				37.5	0.19
Plicatula penicillata	4								12.5	0.19
Striostrea prismatica	3								12.5	0.14

during the period of study were clustered into Group 2 (Figure 4).

The highest species richness of 39 and 33 was found in Tlacopanocha and Manzanillo in 2012, and the lowest in La Angosta in 2014 with 5 species, followed by La Angosta 2015 and Muelle 2012 with 8 species, respectively (Table 5).

4. Discussion

The richness of species of mollusks found, at 89, is higher compared to the studies in the southern Pacific region of Mexico (Valdés-González et al., 2004; Flores-Rodríguez et al., 2007, 2012, 2014; Ríos-Jara et al., 2009); however, this richness of species is lower compared studies conducted in the Gulf of California and Jalisco (northern region) (Holguin-Quiñones et al., 2000; Landa-Jaime et al., 2013; Tripp-Quezada et al., 2014). The main differences between these studies are the type of habitat studied and the methods of collection; studies in the northern region cover a greater variety of habitats, such as root mangroves and subtidal soft bottoms (Table 2).

Gastropoda had the most significant number of species and families, and according to Castillo-Rodríguez (2014), this class is one of the most diverse of the group of mollusks. Bivalvia was the least representative of the species richness; this may be due to the difficulty of collecting bivalves in the rocky subtidal zone (Muñiz-Sánchez, 2015), while in most studies of the Gulf of California and the Mexican Pacific it is the class with the second greatest diversity within the mollusk community. On the other hand, Landa-Jaime et al. (2013) and Flores-Rodríguez et al. (2014) also reported a greater diversity of polyplacophorans.

Muricidae and Columbellidae had the highest number of species, and these families have already been recognized as very diverse in the rocky intertidal zone (Castrejon-Rios et al., 2015; Torreblanca-Ramírez et al., 2017); however, in this study, Calyptreaidae is also recognized as very diverse in the shallow rocky subtidal. On the other hand, except for Muricidae, the families Fasciolariidae, Conidae, and Pisaniidae had high relative abundances in the rocky subtidal, while Torreblanca-Ramírez et al. (2017) reported a high relative abundance of Columbellidae, Lottidae, and Trochidae in the rocky intertidal. The most representative species of the shallow rocky subtidal were *Engina tabogaensis* and *Gemophos sanguinolentus* (Pisaniidae); *Cerithium atromarginatum* (Cerithiidae); *Columbella major* (Columbellidae); *Conus gladiator* and *Conus nux* (Conidae); *Leucozonia cerata* (Fasciolariidae); and *Vasula speciosa* (Muricidae). With the exception of *G. sanguinolentus*, *C. atromarginatum*, and *C. gladiator*, the other 5 species are of commercial importance in Acapulco, Guerrero (Flores-Garza et al., 2012b; Torreblanca-Ramírez et al., 2014).

In 2012, Muelle had the lowest similarity; in this year the government refilled the pier ("Muelle") with an artificial substrate, and this action affected the mollusk

Figure 3. Fifteen dominant mollusk species in the stations sampled in Acapulco, Guerrero, Mexico.

species composition. Christie (1985) pointed out that the deviation of a typical natural pattern may be due to pollution effects; in this case, it was due to a local physical disturbance.

In 2014, La Angosta showed less similarity compared to the other stations, mainly because it is located in a high energy zone, e.g., strong currents and high waves, where only species resistant to these conditions can survive (Lewis, 1964). The analysis of the similarity of all the stations during the three years confirms that La Angosta and Muelle were the stations with the lowest similarity values, mainly due to environmental stress and anthropogenic impact, respectively. Besides, it was observed that after two years the pier, impacted in 2012, returned to its normal state in the composition of the species, which suggests a high resilience of the community. Chapman and Underwood (1996) found that in these environments a period of one month may be sufficient for the recovery of biota.

Fifteen species (17%) of this study are important resources in coastal fishing in Acapulco (Flores-Garza et al., 2012b; Castro-Mondragón et al., 2015); however, this number could increase in Acapulco because 41 species of this study were classified as economically important or with economic potential on the coast of Guerrero (Ríos-Jara et al., 2001; Torreblanca-Ramírez et al., 2014; Galeana-Rebolledo et al., 2018). For example, *Vasula speciosa*, one of the most abundant species in the rocky subtidal zone, is a species of commercial importance for the region. Two species recorded in this study, *Crucibulum scutellatum* and *Pinctada mazatlantica*, are also classified as subject to special protection by Nom-059-Semarnat-2010.

The preceding indicates that the sampling design used in this study could aid in monitoring mollusk species of

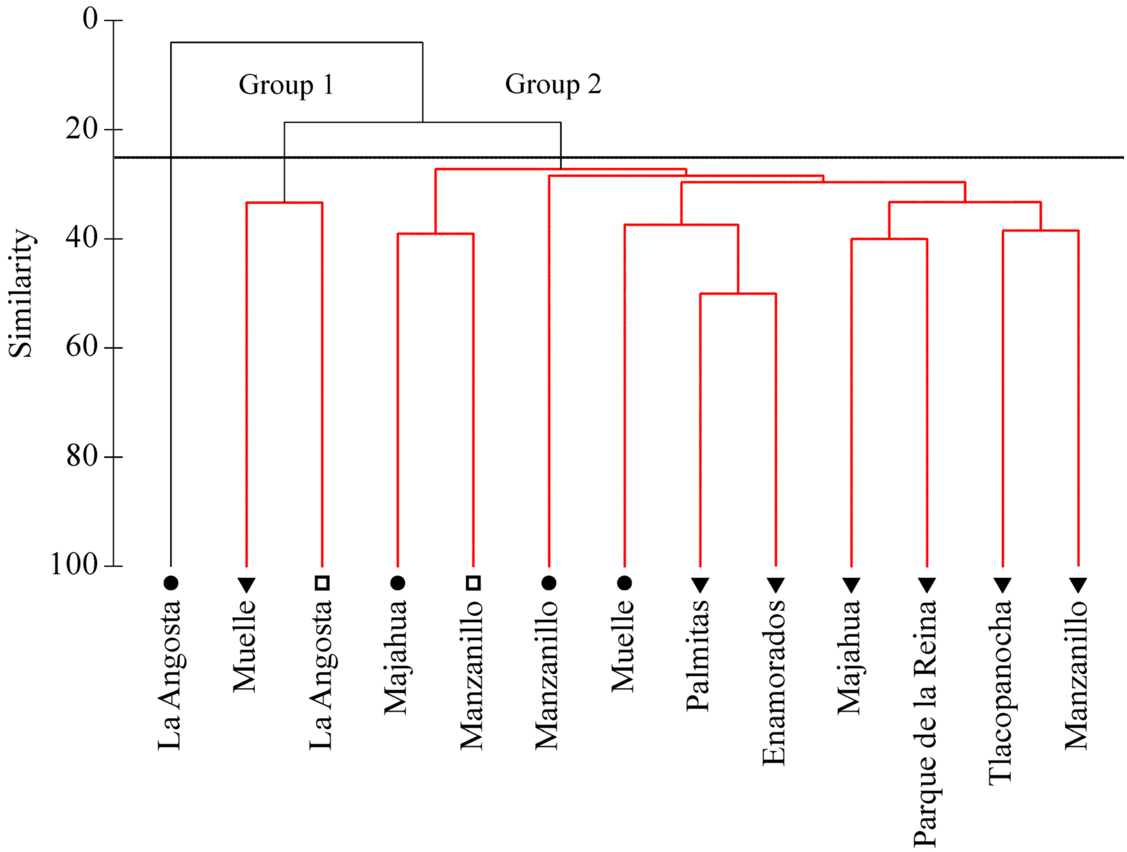

Figure 4. Mollusk species composition affinity among stations for 2012 (▼), 2014 (●), and 2015 (□). G1: Group 1, G2: Group 2. Cutline: 25% similarity.

Table 5. Abundance and species richness of stations during 2012, 2014, and 2015.

Site	Year	Abundance (ind. 3 divers^{-1} h^{-1})	Species richness
Majahua	2012	146	28
Majahua	2014	89	28
Muelle	2012	135	8
Muelle	2014	112	25
Manzanillo	2012	154	33
Manzanillo	2014	118	21
Manzanillo	2015	119	29
Parque La Reina	2012	371	28
Tlacopanocha	2012	296	39
Palmitas	2012	209	20
Enamorados	2012	273	22
La Angosta	2014	16	5
La Angosta	2015	48	8

commercial importance and those under the status of environmental protection. Avoiding the overexploitation of mollusks is important, which has already occurred with other species in the study area; for example, *Megapitaria squalida* G. B. Sowerby I, 1835 is no longer a profitable fishery resource in this area, as it was years ago, because its banks have declined and it requires more effort to find them (Castro Mondragón et al., 2015).

In conclusion, the diversity of mollusks in the shallow rocky subtidal environment of the Acapulco coast is high with 89 species. Most mollusk species found in the rocky subtidal area also inhabit the rocky intertidal zone, and only 10 species of mollusks are restricted to the shallow rocky subtidal. However, Fasciolariidae, Conidae, and Pisaniidae dominated in terms of relative abundance. Furthermore, 46% of the total species recorded in the shallow subtidal area are economically important or with economic potential. In addition, the composition of the mollusk species of Acapulco Bay, Puerto Marques Bay, and the island of Roqueta (protected coast) is similar and more diverse (20–39 species) compared to La Angosta (5–8 species), which is located in a high energy area (exposed coast). The species richness and diversity of mollusks, and in particular the composition of the species, seem to be affected by anthropogenic or natural factors such as the refilling of piers and strong currents. Despite this, the mollusk community of the Acapulco coast has a great capacity for recovery. The information generated in this study can be used by decision-makers for environmental monitoring and management of mollusk species of commercial importance.

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