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Diversity and abundance of reef macro invertebrates (Mollusca; Echinodermata) in the southern Gulf of California, México

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Abstract. Diversity and abundance of macro mollusks and echinoderms were estimated on three protected islands in the southern Gulf of California. From February 2005 to February 2007, each island was visited twice during warm and cold season. These estimates were calculated from a total of 165 belt transects (25 x 2 m). 22 species of echinoderms and 23 of mollusks were identified. Species richness and abundance showed statistical differences among the islands for both phyla; however, diversity did not. Species assemblages were different on each island. Espíritu Santo had more echinoderms and San José had more mollusks. Asteroids were the most abundant, followed by echinoids and holothurians. The dominant species were the sea star *Phataria unifascialis*, followed by the sea urchin *Tripneustes depressus* and the holothurian *Holothuria fuscoscinerea*. Gastropods were the most abundant with 12 species, whilst bivalves had 7. San José and Cerralvo had more gastropods species than Espíritu Santo. The dominant gastropod and bivalve were *Serpulorbis margaritaceus* and *Pinctada mazatlanica* respectively. The echinoderm and mollusk fauna are similar on the three islands, the community structure is stable along the study area; it seems that habitat type has a strong influence on the distribution and abundance of both phyla.

Key words: Echinoderms, Mollusks, Gulf of California, Abundance, Diversity.

Introduction

The Gulf of California, México, is one of the most important areas for reef species conservation worldwide (Roberts et al. 2002). In the Gulf, the NPA "Islas del Golfo de California" comprises more than 100 islands (Anonymous 1986; 2000a). Many of them support artisanal fisheries and tourism activities thus representing an important economic resource. The islands from the southern Gulf (San José, Espíritu Santo and Cerralvo) are characterized mainly by rocky bottoms which support the presence of isolated coral patches and coral communities, particularly in shallow waters around the islands (1-10 m depth). In this area, coral cover is usually less than 10% (Reyes Bonilla et al. 2005a).

Macro invertebrates, especially mollusks and echinoderms (Asteroidea, Echinoidea, Holothuroidea, Gastropoda, Bivalvia, Opistobranchia) are commonly associated to these communities (Keen 1971; Brusca 1980; Maluf 1988; Cintra Buenrostro 2001; Skoglund 2001; 2002; Solís Marín et al. 2005) and some of them are subjected to local fisheries and some are protected by law (Anonymous 1994). Both phyla play an important ecological role interacting actively with other species and therefore influencing benthic community structure (Benedetti-Cecchi 2001; Chapman 2002). Species assemblages depend greatly on resource availability and on the distance to other populations (Hansky 1991; Woodward & Kelly 2002). However, little is known about the patterns of species assemblages. Even though the mollusk and echinoderm fauna is well known in the Gulf of California (Verrill 1870; Ludwig 1893; Holguín Quiñones et al. 2000; Reyes Bonilla et al. 2005b; González Medina et al. 2006; Herrero-Pérezrul et al. 2008), only a few studies have been directed to ecological aspects of these macro invertebrates. The objective of this study was to analyze the community structure of Mollusk and Echinoderms from San José, Espíritu Santo and Cerralvo discussing some ecological aspects such as abundance, dominance, species richness and diversity.

Material and methods

The islands San José (SJI), Espíritu Santo (ESI) and Cerralvo (CRI) (Fig. 1) were visited twice from February 2005 to February 2007, considering two seasons, warm (Jun-Nov) and cold (Dec-May). A total of 165 (25 x 2 m) belt transects were used to assess the macro invertebrate community on the three islands. Community structure was monitored through the estimation of abundance and frequently used

ecological indexes (Magurran 2004). We calculated the Shannon-Weaner's diversity index (H´), which considers the proportion of the abundance and species richness from the sample and was calculated with the formula:

$$H' = -\Sigma (p_i) (\log_{10} p_i) \quad (1)$$

where: H' = data from the sample in bits/individual; s=species number; p_i = proportion of the total sample in the i-th species.

Data were tested for homoscedasticity using a Kolmogorov-Smirnoff test. A one way ANOVA (α=0.05) was used to compare differences amongst the island's index and used a Tukey test to detect the origin of differences (Zar 1999).

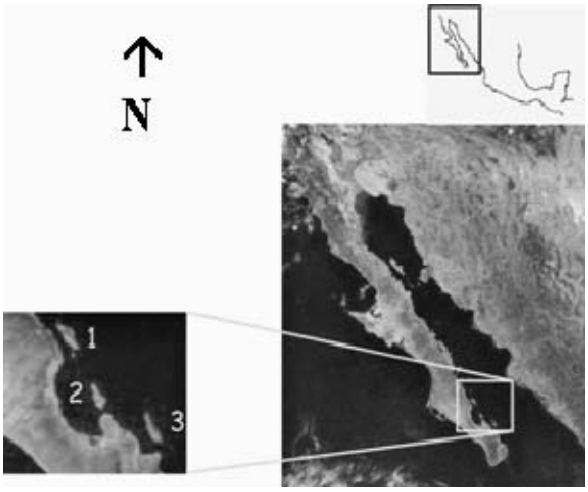

Figure 1. Study area. **1**. San José is located at 25°6'N, 110°31'W; **2**. Espíritu Santo at 24° 4'N, 110°27'W; **3**. Cerralvo at 24°8'N, 109°47'W.

Results

During this study, we counted a total of 5310 echinoderms belonging to 23 species (12 asteroids, 7 echinoids and 4 holothurians) (Table 1); and a total of 2264 mollusks belonging to 22 species (9 gastropods, 7 bivalves and 6 opistobranchs) (Table 2). Species richness of echinoderms and mollusks was not statistically different amongst the islands ($F_{2,26}$= 2.4397, P = 0.09084 and $F_{2,26}$ =1.0643; P =0.36136, respectively). Despite the similarity in richness, the species assemblages were different on each island.

The Class Asteroidea was the best represented on the island complex, followed by Echinoidea and Holothuroidea. The abundance of echinoderms showed statistical differences between the islands ($F_{2,26}$=4.0437, P=0.02958). The Tukey test detected that ESI had the highest values with more than 2500 individuals belonging to the three classes, followed by SJI with almost 2000 individuals, and CRI with less than 1000. At class level, Asteroid abundances also showed statistical differences between the islands ($F_{2,26}$=8.8096, P=0.0012), but holothurians did not ($F_{2,26}$=2.7287, P=0.0942).

The most abundant species was the sea star *Phataria unifascialis,* found ubiquitously along the three islands, followed by the sea urchin *Tripneustes depressus* and the sea cucumber *Holothuria fuscoscinerea*. The commercial holothurian *Isostichopus fuscus* had the lowest abundance (0.07 $\pm$ 0.006 ind/m^2).

Table 1. List of Echinoderm species. * Species observed at the study site but not counted.

Asteroidea	Echinoidea	Holothuroidea
Achanthaster planci	*Arbacia incisa*	*Euapta godeffroyi*
Asteropsis carinifera *	*Centrostephanus coronatus*	*Holothuria fuscoscinerea*
Astrometis sertulifera *	*Diadema mexicanum*	*Holoturia kefersteiini*
Echinaster tenuispina *	*Echinometra vanbrunti*	*Isostichopus fuscus*
Heliaster kubiniji	*Eucidaris thouarsii*	
Linckia columbiae	*Toxopneustes roseus*	
Linckia guildingui *	*Tripneustes depressus*	
Mithrodia bradleyi		
Nidorellia armata		
Pentaceraster occidentalis		
Pharia pyramidatus		
Phataria unifascialis		

Table 2. List of Mollusks species. * Species observed at the study site but not counted.

Bivalvia	Gastropoda	Opistobranchia
*Chama frondosa**	*Cerithium uncinatum**	*Elyisia diomedea*
Hyotissa hyotis	*Chromodoris norrisi*	*Glossodoris sedna*
Nodipecten subnodosus	*Conus sp.*	*Hypselodoris ghiselini*
Pina rugosa	*Murex tricoronis* *	*Navanax aenigmaticus*
Pinctada mazatlanica	*Muricanthus princeps*	*Tambja abdere*
Pteria sterna	*Plicopurpura patula pansa*	*Tambja eliora*
Spondylus calcifer	*Serpulorbis margaritaceus*	
	Strombus galeatus *	
	Thyca callista *	

Regarding mollusks, the community analysis showed that gastropods were the most abundant, followed by bivalves and opistobranchs. The species richness of gastropods showed statistical differences amongst the islands ($F_{2,26}$= 6.8816; P = 0.00503), with the highest value at SJI and the lowest at ESI (Fig. 2). Bivalves were slightly more abundant at ESI and less at CRI, however, no statistical differences were detected ($F_{2,26}$=1.0643; P =0.36136).

The most abundant mollusk was the gastropod *Serpulorbis margaritaceus*, followed by *Muricanthus princeps*. It is important to emphasize the common presence of the mother of pearl *Pinctada mazatlanica*, which amongst the bivalves showed the highest density (0.052 ± 0.03 ind/m^2).

Echinoderms were more diverse than mollusks, but no statistical differences were observed on diversity estimates amongst the islands for both phyla ($F_{2,26}$=2.04, P= 0.3597 and $F_{2,26}$=3.2614, p=0.05448 respectively) (Fig. 3).

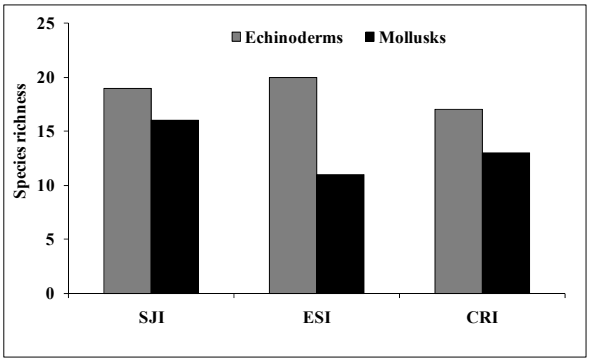

Figure 2. Species richness amongst islands.

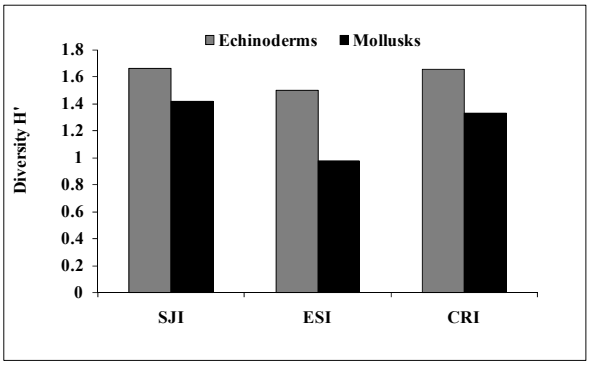

Figure 3. Diversity of echinoderms and mollusks amongst islands.

Species assemblages of echinoderms were different on each island, except for asteroids. The echinoid *Tripneustes depressus* was more abundant in SJI, whilst in ESI was *Eucidaris thouarsii* and in CRI was *Toxopneustes roseus*. Regarding holothurians, *Holothuria fuscoscinerea* was the most abundant and was commonly observed on the three islands, however, *Euapta godeffroyi* was more abundant in ESI and *Isostichopus fuscus* in CRI. Except for the gastropod *Serpulorbis margaritaceus,* the same behavior was observed for mollusks. Gastropods were similarly abundant on the three islands, but bivalves were more abundant in ESI and opistobranchs in SJI. The bivalve *Pinctada mazatlanica* and the gastropod *Muricanthus princeps* were more common at ESI. The images of the dominant species are depicted in (Fig. 4). The holothurian *Isostichopus fuscus* is also shown because of its protection *status* and high importance as an economic resource.

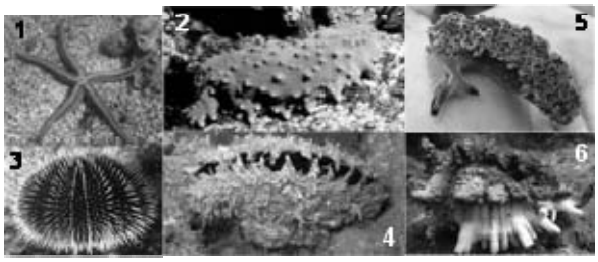

Figure 4. Dominant species at the study site. 1 *Phataria unifascialis*; 2 *Isostichopus fuscus*; 3 *Tripneustes depressus*; 4 *Pinctada mazatlanica*; 5 *Elysia diomedea*; 6 *Muricanthus princeps*.

Discussion

Field visual observations corroborated the number of species of macro mollusks and echinoderms found by census. Since the insular complex involved rocky bottoms, it is possible that some species might have been overlooked due to their habits. Particularly echinoderms were commonly observed hidden in crevices, small caves and between coral branches. Similarly, the gastropod *Serpulorbis margaritaceus* was abundant and frequently counted between coral branches of *Pocillopora* spp. Coral communities and patches from the study area are dominated by *P. verrucosa* and *Porites panamensis* (Gastil et al. 1983; Reyes Bonilla et al. 2005a), and the important role of corals as refuge and substrate for many invertebrates is well known (James 2000, 2006).

The number of macro-echinoderm species varies along the Gulf of California, increasing towards tropical latitudes (Maluf 1988; Cintra Buenrostro 2001), however, it seems that the community structure of echinoderms in the Gulf is relatively homogeneous and is dominated by asteroids (Reyes Bonilla et al. 2005b; Herrero-Pérezrul et al. 2008). At the study site, echinoderms were more abundant and diverse than mollusks. For both phyla, despite the fact that diversity showed no statistical differences among the islands, the species assemblage was different. This is probably related to habitat type. ESI is characterized by a number of shallow bays favoring coral communities and species associated to them. On the other hand SJI and CRI bottoms are mainly composed by boulders and coral communities are less abundant (Reyes Bonilla et al. 2005a).

Regarding echinoderms, asteroids showed the highest value of species richness. It is important to mention that *Phataria unifascialis* was the dominant species, the high values could explain the statistical differences amongst the islands. Some authors consider this sea star as herbivorous (Reyes Bonilla et al. 2005b). During early 1980's the dominant sea star in the Gulf of California was *Heliaster kubiniji*, a

carnivorous sea star, however, in subsequent years, its populations decreased drastically, probably due to the effects of ENSO 1983 or maybe a pathogen (Dungan et al. 1982). *H. solaris* decreased its abundance in the Galápagos Islands after the 1983 ENSO (Hickman 1998). To this date *H. kubiniji* shows no sign of recovery, and it is now considered as rare due to its low densities (Herrero-Pérezrul et al. 2008). It possible that this species shift from carnivorous to omnivorous had some effects on the community structure, however, there is not enough data to support or reject this argument.

On the other hand, we have the presence of *Acanthaster planci*, a well known coral predator. This asteroid had low densities (0.022 ± 0.0016 ind/m^2), it is interesting to notice that it was more commonly observed on rocky bottoms feeding on bryozoans and octocorals. This is easily explained by the fact that in the study area, coral cover is very low (Reyes Bonilla et al. 2005a), thus, there is not enough coral to feed on and it must feed on what is available.

Other important echinoderm is the holothurian *I. fuscus*, which is currently under especial protection by the Mexican government (Anonymous 2000b). The low abundances found in the study site may be caused by legal fishing activity, however, it is possible that these values were also influenced by small (but constant) levels of illegal fishing.

Regarding mollusks, the relatively high abundance of the mother of pearl *P. mazatlanica* is worthwhile to mention. This bivalve was considered an endangered species since early 20th century, and even though data on abundance of wild populations are old and scarce, there is some evidence of an increase on density population (González Medina et al. 2006), and in this study density was even higher that that reported by the authors. It seems that the protection has served its purpose.

One of the most curious mollusk found in this study was the gastropod *Thyca callista*, which parasites *P. unifascialis*. It was not counted on the census, because is mostly hidden on the oral surface of the sea star and is not visible. However, it seems that its presence is common in the Gulf of California (Salazar and Reyes Bonilla 1998, Herrera Escalante 2005). This could be explained by the fact that *P. unifascialis* is more abundant in the Gulf than in the rest of the Pacific coasts of México.

In conclusion, the echinoderm and mollusk fauna are similar on the three islands. The community structure is stable along the study area; it seems that habitat type has a strong influence on the distribution and abundance of both phyla.

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