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Effect of hurricane John (2006) on the invertebrates associated with corals in Bahía de La Paz, Gulf of California

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Abstract. During the last four years, quarterly visual censuses were conducted on reef communities at six sites around Bahía de La Paz (La Paz bay) using belt transects (10 × 1 m, n = 5 replicates per site). The present study documents the effect of one hurricane on the reef invertebrate's assemblage found at these sites by comparing community structure and abundance before and after the passage of hurricane John (September 2006, level II Safir/Simpson—winds of 215 km/h). On July 2006 (prior to the hurricane), visual censuses revealed 50 species and 3093 specimens, whereas in October 2006 (after the hurricane) 39 species and 2018 specimens were found, with a similarity index of 83.1% between these two surveys. There were 13 species that were not seen after the storm and three species were registered as "new" after the hurricane. The group most affected was the Echinoderms, with six species lost. The sighting of new species was mainly for the crabs, with two species. One year after the hurricane (October 2007), the recovery of the community was 38% of richness, with the addition of five species (three Echinoderms and two Mollusks) that were lost after the hurricane.

Key words: Monitoring, Reefs, Succession, Visual censuses.

Introduction

Marine invertebrates are important components in benthic communities where, among other functions, play an essential role by transferring energy up to higher trophic levels. For the Gulf of California, México, numerous studies on invertebrates have been conducted (i.e., Brusca 1980; Wicksten 1983; Villalobos et al. 1989; Hendrickx 1993). However, most of these papers were prepared under a taxonomic perspective and based on collections and voucher specimens from museums.

Bahía de La Paz (located in the southern Gulf of California, near the city of the same name) is probably the best studied location in the Gulf of California because of the presence of several marine sciences institutes in the area (Solís-Marin et al. 1997; González-Medina et al. 2006). Systematic checklists of different taxonomic groups such as fish (Castro-Aguirre and Balart 1997), echinoderms (Solís-Marin et al. 1997), mollusks (Holguín-Quiñones and García-Domínguez 1997), and decapods (Pereyra 1998; Hernández 1999) are available for this area. Many of these studies were performed on coral areas, where researchers used destructive methodologies to obtain specimens. These procedures were "acceptable" in the past, but after the mass mortality of corals occurred because of the increase in water temperature brought upon by the El Niño Southern Oscillation (Reyes-Bonilla 2001), there is growing concern that destructive sampling can exacerbate the natural degradation of these fragile systems. To avoid this problem, descriptive studies are now conducted chiefly using visual census methods.

The southern Gulf of California (where La Paz is) suffers the frequent impacts of hurricanes and tropical storms, but there are few studies on the damage that these disturbances exert on marine communities, and especially on the coral reefs of this area. Only Reyes-Bonilla (1993, 2003) and Glynn (2001) have provided information on this topic and described how hurricanes have actually caused limited damage to the urchin and fish populations; moreover, the hurricanes sometimes have even benefited coral dispersal by an increase in fragmentation. Considering the dearth of available information, the objective of this paper was to illustrate changes to the invertebrates' assemblages in coral habitats after the passage of a strong hurricane. Our results show how the impacts were immediate and sustained, as one year after the perturbation, the assemblages had not returned to their original state.

Material and Methods

Bahía de La Paz is located in the southwestern Gulf of California between 24° 11´ to 24° 40´N, and 110° 20´ to 110° 42´W. On September 2006, hurricane John (level II Safir/Simpson—winds of 215 km/h) impacted the area (Fig. 1) and caused severe disturbance to the benthic communities along its path. In the present study, surveys were conducted in July 2006 (before the hurricane), October 2006 (after the hurricane), and one year after the event (October 2007), in order to measure the impact and potential recovery of invertebrate assemblages.

Surveys were conducted on coral reefs or communities (sensu Reyes-Bonilla 2003) at four sites using belt transects (10×1 m, n = five replicates per site). A SCUBA diver visually identified and counted the invertebrates seen inside the belts. The taxa surveyed included mollusks (Gastropoda), sea urchins (Echinoidea), sea stars (Asteroidea), decapod crustaceans (Anomura, Brachyura, and Caridea), and polychaetes (Annelida). From these records, several community descriptors (Magurran 2003) were calculated to compare the structure of the communities over time [similarity (Bray-Curtis coeff-

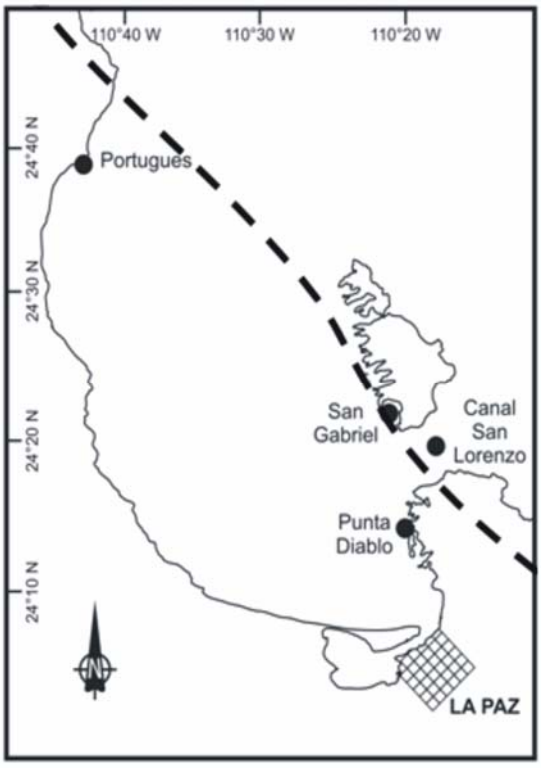

Figure 1: Study area (Bahía de La Paz) and survey sites. The dashed line shows the trajectory of hurricane John (August-September 2006).

icient), diversity (Shannon-Wiener index), and evenness (Pielou index)]. We used a non metric multidimensional scaling (Clarke and Gorley 2006) to map the degree of similarity among sampling sites (before, after, and one year after the hurricane). A cluster analysis was applied to view the similarities in species richness among sampling dates (July 06, October 06, and October 07). Comparisons among surveys at each site were done using 1 way ANOVA.

Results

Species richness and abundance of invertebrates decreased after the passage of the hurricane; the change was remarkable as these descriptors were down from 20% to 30% of initial (Table 1). In contrast, the diversity and evenness practically remained the same. To confirm that changes were caused by the hurricane and do not represent the seasonal variation, we plotted the annual density on July and October from 2005 to 2007 (Fig. 2). In the graphic is evident that the average density on October 2006 was lower than in 2005 and 2007 and the difference is statistically significant ($F= 4.94$, $p<0.05$). This found represents the hurricane effect on the invertebrates' assemblage.

Table 1. Community parameters of invertebrates' assemblage in La Paz bay before and after hurricane John (S= species richness; N= abundance, J´=evenness, H´= diversity).

	S	N	J´	H´
July 06 (Before)	50	3093	0.94	3.67
October 06 (After)	39	2018	0.96	3.51

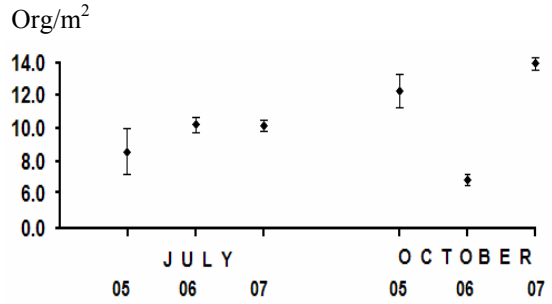

Figure 2: Density of invertebrates including the same months one year before and one after the hurricane, to show annual tendencies. (average ± standard deviation).

There were also changes in species composition. Fourteen species found before the hurricane (July 06) were not observed after the storm (October 06). The most sensitive group was the echinoderms with seven species lost (i.e. *Amphiaster insignis, Euapta godefroyi, Isostichopus fuscus*) followed by mollusks with five species (i.e. *Megapitaria squalida,*

Muricanthus nigritus, Nodipecten subnodosus), and crustaceans and annelids with one species each.

On the other hand, Crustaceans practically did not change in abundance from 897 individuals before the hurricane, to 908 just afterwards. Remarkably, their numbers rose to >2500 individuals one year after the perturbation. Within this group, the opportunistic, coral-symbiotic crustacean species were the most abundant (Table 2).

Table 2. Abundance of most sensitive species before and after hurricane John (July 06 vs. October 07). Groups: Cru =Crustaceans, Ech = Echinoderms, Mol =Mollusks. * = Symbiotic to pocilloporid corals.

Group	Species	Jul 06	Oct 07
Cru	*Alpheus lottini**	191	488
Cru	*Calcinus californiensis*	22	61
Ech	*Diadema mexicanum*	123	18
Ech	*Echinometra vanbrunti*	319	89
Cru	*Harpiliopsis depressa**	192	718
Cru	*Harpiliopsis spinigera**	80	507
Cru	*Neaxius vivesi*	58	2
Mol	*Quoyula madreporarum**	30	115
Cru	*Trapezia ferruginea**	251	538

A comparison of similarity among sites based on species composition and abundance was performed whit data taken just after de hurricane (October 06). The community at San Gabriel reef was very different from the rest, although this difference was not significant (stress > 0.10: Fig 3).

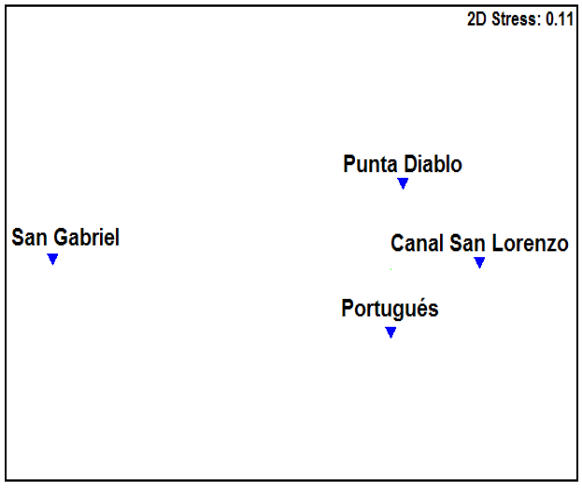

Figure 3: nMDS of invertebrates' abundance on the sampled sites.

Comparisons over time indicated that species richness after the disturbances (October 2006 and October 2007) were more similar between them, than those sampled prior to the storm (Fig. 4).

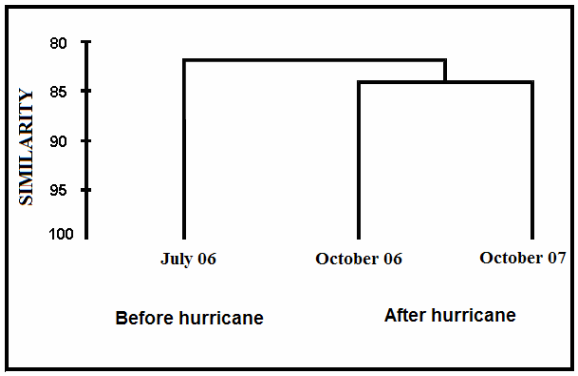

Figure 4: Similarity cluster (Bray-Curtis) on species richness of invertebrates from Bahía de La Paz before and after hurricane John.

Discussion

The present study showed that community parameters changed after the hurricane. Commonly, after any disturbance in this kind of ecosystems, dominance decreases and diversity increases (Rogers 2003). However, in the present study, we detected important changes in richness and abundance, whereas evenness and diversity remained at similar levels. The slight increase in equitability (Table 1) was maybe related to a more equal distribution of abundance among the species, caused by the change in the substrate heterogeneity promoted by the storm. However, in the present study diversity and evenness did not change significantly with time. As these markers are defined by an interaction of richness and relative abundances (Salazar-Vallejo 2002), we suggest that species replacements after the hurricane may have caused the detected stability.

The physical damage caused by hurricanes can be considerable. Lugo-Fernández et al. (1994) showed that waves were the main agent that caused changes in Margarita reefs (Puerto Rico). At San Gabriel, coral pieces broken by the hurricane covered the sandy-gravel bottom and, thus, caused some sedentary species to be removed, including the clams *Megapitaria squalida* and *Nodipecten subnodosus*. On the other hand, organisms that are usually not seen in visual surveys (i.e., the crab *Eriphia squamata*, the clam *Pinna rugosa*), were exposed by the broken corals after the hurricane (October 2006). Notwithstanding the higher probability of observing specimens, richness was still lower than before the storm (July 2006). Thus, the hurricane caused an immediate greater impact on species richness, and also qualitatively changed the community.

In addition, coral fragmentation caused by the hurricane at San Gabriel promoted an increase in availability of coral substrata and, as a consequence, there was an increase in abundance one year after the

storm compared to previous dates. Interestingly, most of the higher abundances were due to the arrival of coral-symbiotic species (Table 2).

One year after the hurricane John (October 2007), there were numerous echinoderm and mollusk recruits, which will likely recover baseline conditions in the reef areas visited. Rogers (2003) stated that the recovery of any community will depend, on the natural resilience of the species that compose the community. In the case of La Paz, there were no hurricanes of consideration in 2007 and 2008; if this trend continues, it is feasible that the conditions may improve in years to come. In the absence of storms, an increase in the abundance and richness concomitant with a less homogeneous community where the dominant taxa will regain their advantage would be expected.

In the present study, the before-after comparison was accomplished thanks to a monitoring program that was initiated in 2005 using methods that do not disturb the corals and associated fauna (Halford and Thompson 1994). Visual surveys present advantages over destructive techniques in the study of disturbed areas, as the corals suffer no further harm. Finally, the results presented here serve as a baseline inventory of coral-associated invertebrates for future evaluations. The data collected will also help local environmental authorities in the monitoring and management of protected areas, especially considering that San Gabriel reef is now part of a recently established National Park.

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