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Mapping benthic faunal communities in the shallow and deep sediments of Las Perlas Archipelago, Pacific Panama

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ABSTRACT

Las Perlas Archipelago (LPA) is located off the Pacific Coast of Panama and was designated as a marine protected area (MPA) in 2007. This baseline study of the shallow and deeper sedimentary habitats of the islands partly informed the MPA designation. Ninety-two grab stations and twenty trawl stations were sampled. Sediment grab sample results were interpolated to produce a map that showed the area to be dominated by mud (1246 km^2, 40%) and sand/shell sediments (780 km^2, 25%). A total of 201 taxa were recorded and over 5800 individual specimens were processed, revealing that the sediments hold varying community compositions, with annelids being the dominant group (73%) followed by crustaceans (14%). Relationships were evident between community, feeding guilds, and sediment types, which give an indication of communities that can be expected in similar sediments in other areas of the Tropical Eastern Pacific. A study of this scale and level of detail is rare for this biogeographic region and provides a valuable, comprehensive appreciation of the LPA's benthos.

1. Introduction

Marine soft sediments comprise one of the largest and oldest habitats in the world but these habitats, their communities and patterns of species richness are greatly understudied (Gray, 2002; Zajac, 2008). Survey work is a vital element in defining the composition, distribution and condition of soft sediment habitats and, traditionally, studies that have been conducted to collect quantitative biological data have relied on core or grab samplers with sampling stations that are regularly dispersed over the survey area (Hewitt et al., 2004). Faunal components of marine soft sediments are also more often targeted for monitoring work (compared to pelagic communities) as it is possible to gather many species in one grab, they are relatively sessile and cover a range of feeding and reproduction types so that change detection is easier (Gray, 2002). However, it is widely recognized that more research is required into soft sediments, especially in tropical and sub-tropical areas (Jackson, 1994; National Research Council, 1995; Gray, 2002). Previous studies in these areas include both regional and localized studies of, for example, Kingston Harbour in Jamaica (Wade, 1972), Gray's Reef National Marine Sanctuary, Florida (Hyland et al., 2006), the mid-Atlantic (Bergstad and Gebruk, 2008), Singapore, Asia (Lu, 2005), Victoria, Australia (Coleman et al., 1978), southern Californian continental shelf (Bergen et al., 2001), Gulf of Nicoya (Maurer and Vargas, 1984; Vargas, 1987) and Golfo Dulce, Costa Rica (León-Morales and Vargas, 1998). These studies, and others (in temperate regions, e.g. Zajac et al., 2000; McBreen et al., 2008), have shed some light on ecological patterns between benthic sediment communities and environmental variables, particularly differences in benthic community composition in relation to sediment type and particle size. This is supportive of the general theory that, because organisms live in or on the sediment, have specific preferences for particle size and have a reliance on the sediment for feeding (e.g. deposit feeders), there should be a measurable relationship between the two (Etter and Grassle, 1992). Additionally some studies have also found depth to be an influential variable (Etter and Grassle, 1992; Bergen et al., 2001; Hyland et al., 2006) although, as Gray (2002) points out, gradients of sediment properties can also vary with depth.

Such field studies are fundamental in selecting priority areas for conservation, long-term management and further understanding of ecological patterns (McBreen et al., 2008). Marine conservation in Pacific Panama has advanced considerably in the last 15 years

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since the establishment of the first marine and coastal protected area, the Coiba National Park, in 1991. Due to the conservation status of Coiba National Park, there have been several marine habitat surveys within its boundary, including studies in intertidal and shallow waters that have increased our knowledge of the region's polychaete species (Capa et al., 2001a,b; López et al., 2002; Aguado and San Martín, 2006). However, whilst there was a strong feeling that the Las Perlas Archipelago (LPA) in Pacific Panama also required similar protection, the information on the distribution of both sedimentary and reef habitats and their associated fauna for the Archipelago's marine areas was not at a scale or level of detail required for the selection of priority conservation areas and the development of management plans. In April 2003, a five-year research study started to gather habitat information for the LPA as evidence to use in discussions with the Panamanian Government regarding the designation of a marine protected area within the Archipelago's boundaries. This area was finally designated in 31st May 2007 under Law No. 18. During the process, numerous investigations on its marine ecology and biological resources were carried out including: the mapping of shallow water habitats from satellite data combined with ground truthing (Benfield et al., 2007); distribution and diversity of coral reefs and coral communities (Guzman et al., 2008a); a comparison of coral and rocky reef fish assemblages (Benfield et al., 2008); population assessments of the scallop *Argopecten ventricosus* (Medina et al., 2007), the Pacific green spiny lobster *Panulirus gracilis* (Guzman et al., 2008b) and the queen conch *Strombus* (Cipriani et al., 2008); and ecology of sabellarid worm reefs (Barrios et al., in press).

The purpose of the study described here was to systematically map the distribution of the benthic sediment types and to provide an inventory of their associated faunal communities in water depths down to 120 m around the LPA in order to feed into the conservation designation and subsequent management of this area along with the aforementioned other studies. Benthic sediment surveys of extensive deep water areas are extremely limited in the Tropical Eastern Pacific (TEP). Therefore this study is a rarity in terms of its nature, scale and level of detail and it provides a complementary and a more comprehensive assessment of the marine seabed habitats and fauna particularly in offshore and deeper areas of the LPA and TEP.

2. Methodology

2.1. Study site

The LPA lies between 08°40′19″N, 79°03′49″W and 08°11′46″N, 78°46′31″W within the Gulf of Panama (Fig. 1). It is composed of over 2050 mostly uninhabited basaltic rock islands and islets that lie within the 50 m isobath and falls within the TEP biogeographic zone. The LPA experiences an up-welling period during the dry season (January–April) that results in plankton blooms and high marine productivity. The mean tidal range for the archipelago is 3.8 m (D'Croz and O'Dea, 2007). The marine habitats of the LPA are influenced by El Niño Southern Oscillation events, sedimentation, pollution, over-fishing, and current and unplanned coastal tourism developments.

2.2. Survey method

Fig. 1 shows the location of the study area and the benthic grab and trawl sample stations around the LPA. The stations were located evenly and on a systematic grid throughout the waters surrounding the Archipelago at predetermined locations within (and some outwith) the proposed marine protected area. Sample stations were separated by approximately 5 km unless the geography of the islands prevented this. Ninety two stations were sampled quantitatively around the Archipelago during two cruises (5–14th August 2003 and 8–9th October 2003) using a 0.1 m^2 van Veen grab. At each station three replicate benthic grab samples were taken, one for sediment analysis and the contents of the other two were processed for benthic fauna. The vessel was repositioned as necessary over the station within 50 m to allow for collection of replicate samples. Twenty stations were also sampled using a trawl deployed from an A-frame on the research vessel. The trawl data were not quantitative and more used to gather supplementary information on larger mega faunal specimens only. For those stations where trawls were conducted, only one trawl tow was undertaken.

2.3. Sample processing

Samples for sediment analysis were frozen until required. In the laboratory these samples were assessed for particle size distribution by passing dried sub-samples through a stack of differently sized mesh sieves and the samples were classified using the Wentworth scale. The percentages of organic carbon and carbonate were also derived by oven drying and recorded. Samples for biological analysis were gently washed on board the survey vessel and the fauna retained by a 1000 μ mesh sieve were preserved in a mix of formalin in sea water and stained with Rose Bengal. The samples were returned to the laboratory for processing and analysis. Samples were poured into a 500 μ mesh sieve, gently cleaned with fresh water and then transferred to a white enamel sorting tray. All organisms were removed, identified to family level where possible and stored in glass vials filled with 70% ethanol. These samples were then transferred to the National Museums of Scotland, Edinburgh where they have been curated and are available for further research.

2.4. Data analysis

Multivariate analyses of benthic composition in the LPA were carried out using the software PRIMER 4.0 and stations without individuals were dropped off these analyses (Clarke and Warwick, 1994). The abundance data of the taxa/grab stations matrix, were transformed by log $(x + 1)$ and cluster analysis was performed using Group Average Linkage and Euclidean distance measure to determine groups of stations based on faunal composition (Clarke and Warwick, 1994). Principal component analysis (PCA) of the same data was carried out and an initial inspection of the relative importance of each axis (from the percentage of the total variance explained by each) showed that only the first two axes were of significance. PCA bi-plot was used to show the ordination of stations and the direction and the rate of increase in abundance of each taxon was represented by arrows (*sensu* Quinn and Keough, 2002). Additionally, the ANOSIM test was used in order to determine if faunal assemblages of the stations were more similar within groups that between groups. The value of R determines the level of difference, $R = 1$ is total difference between groups (Clarke and Warwick, 1994). Finally, Pearson correlations of total abundance and taxa richness per station with PCA axis and environmental variables were used to find the spatial trends of the biodiversity in the LPA.

3. Results

3.1. Descriptive results

A point shapefile of the grab stations was created in ArcGIS and each station assigned its broad sediment structure, determined