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Surf zone fauna of Ecuadorian sandy beaches: Spatial and temporal patterns

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ABSTRACT

Sandy beaches and their surf zones are the most common open shoreline habitat; however, surf zone fauna in the tropics is one of the least studied communities in the world. In the current study, we tested the hypothesis that Ecuadorian surf zone hyperbenthos (invertebrates and vertebrates 1–5 mm in length) and epibenthos (fish and macrocrustaceans > 5 mm in length) vary among beaches and seasons. Therefore, the fauna was described and related to environmental variables. In addition, indicator taxa were identified. The hyperbenthos was divided into holo- and mero-hyperbenthos depending on whether taxa were present during their entire life or only early life stages, respectively. Samples were collected at eight different beaches during the wet, dry and intermediate or transitional season during the low spring tide, from 1999 to 2000, using a hyperbenthic sledge and epibenthic trawl. A total of 447 hyperbenthic and 30 epibenthic taxa were collected, most of which were crustaceans and fish, respectively (52 and 60% of taxa). The mysid, *Metamysidopsis* sp., was the most abundant member of the hyperbenthos (average ± SD: 14,425 ± 40,039 ind. 100 m^{-2}, present in 92% of samples collected), and the swimming blue crab, *Areneus mexicanus*, was the most encountered species among the epibenthos (1 ± 1 ind. 100 m^{-2}, 97% of samples collected). All faunal groups varied among beaches, while the holo-hyperbenthos and less strongly the epibenthos varied among seasons. Variability in the three faunas among beaches, distance from the continental slope and the Guayas estuarine system, and beach water physical characteristics were all strongly correlated suggesting adjacent habitats can influence surf zone biological communities and water physical characteristics. Seasonal effects were related to changes in water physical characteristics among seasons potentially reflecting changes in oceanic currents. These results suggest that, similarly to other beaches around the world, Ecuadorian surf zone fauna is abundant, diverse, and vary among beaches and, for some faunal groups, among seasons, potentially due to the influence of adjacent habitats and seasonal changes in oceanic currents.

1. Introduction

Sandy beaches and their surf zones account for approximately three quarters of the World's open shorelines (McLachlan and Brown, 2006; Mees and Jones, 1997). This large ecosystem serves as habitat for a diverse and abundant fauna, and provides essential ecosystem services such as water filtration, nutrient cycling, wildlife support, and nursery habitat for fish and crustaceans. Sandy beach surf zones are semi-enclosed ecosystems that extend from the sandy beach shoreline to the last breaker and in which there is continuous but variable exchange of water between the surf zone and offshore waters (McLachlan, 1980a). The main factors that are predicted to influence the sandy beach/surf zone ecosystem in the next few decades are climate change and human development (Defeo et al., 2009).

Based on species size and sampling methodology, the surf zone community can be divided into several compartments, including hyper and epibenthos (Marin Jarrin and Shanks, 2011; McLachlan and Brown, 2006; Mees and Jones, 1997). The hyperbenthos is a diverse group of invertebrate and vertebrate species, between 1 and 5 mm in length, that live in the water layer close to the seabed (McLachlan and Brown, 2006; Mees and Jones, 1997; Munilla et al., 1998). This fauna of small species is itself often divided into holo- and mero-hyperbenthos depending on whether the species are present during their whole life or only during their early life stages, respectively, because these respond

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in different ways to environmental factors (McLachlan and Brown, 2006). Common examples of the holo-hyperbenthos include mysids, amphipods and copepods. Brachyuran and anomuran larvae, penaeidean postlarvae and fish larvae are typical representatives of mero-hyperbenthos (McLachlan and Brown, 2006). The epibenthos are animals that live on the seafloor and include demersal fish, echinoderms and crustaceans >5 mm in length (Marin Jarrin and Shanks, 2011; McLachlan and Brown, 2006).

The holo-, mero-hyperbenthos, and epibenthos have been thoroughly studied around the world, particularly in temperate and subtropical areas (McLachlan and Brown, 2006; Mees and Jones, 1997). In the tropics, the few studies that have been conducted found that the surf zone fauna is composed of similar taxonomic groups as those present in temperate areas, but present higher species densities and richness than at higher latitudes (Dominguez-Granda et al., 2004; Melo et al., 2010; Ortega et al., 2014; Ross, 1983). Around the world, these three faunal groups can vary spatially within and among surf zones influenced by beach topography, water movement and circulation, and adjacent habitats (Beyst et al., 2002; Dominguez-Granda et al., 2004; Gillanders et al., 2003; Munilla et al., 1998; Strydom, 2003), and temporally among tides, seasons and years due to local and regional environmental variables and species life cycles (Beyst et al., 2001; Gibson et al., 1993; Hager and Croker, 1980; Marin Jarrin et al., 2015).

In Ecuador, two studies have analyzed the variation of the hyperbenthos but none included the epibenthos (Dominguez-Granda et al., 2004; Marin Jarrin et al., 2015). These researchers observed that the Ecuadorian hyperbentos on a single beach is affected by local physical characteristics (Dominguez-Granda et al., 2004). Further differences were observed between the hyperbenthos of an exposed beach that is located next to the Guayas River, the largest estuarine system in western South America (Twilley et al., 2001) and a protected beach on the Santa Elena peninsula (referred to as Salinas 2 in the present study) that is the most eastern point of South America and closest to the continental slope (Marin Jarrin et al., 2015; Nieto, 1996). Temporally, this fauna was found to vary between the dry and wet seasons that occur in Ecuador but not among tides (Dominguez-Granda et al., 2004; Marin Jarrin et al., 2015). We built on these and other previous studies conducted on tropical, subtropical and temperate beaches, and hypothesized that the Ecuadorian holo-, mero-hyperbenthos and epibenthos would vary among beaches and seasons. To test this hypothesis we (1) described the three faunal groups collected at eight beaches spanning > 150 linear km, (2) compared faunal composition, total faunal densities and taxon richness among beaches and seasons, (3) explored if faunal variability was related to beach distance from other habitats (i.e., rivers and high seas past the continental slope), changes in water physical characteristics of oceanic currents (i.e., water temperature, salinity, water clarity and chlorophyll *a*), and local physical characteristics (i.e., beach exposure, sediment granulometry and beach slope), and (4) identified indicator taxa for the investigated beaches and seasons.

2. Materials and methods

2.1. Study region and beach physical characteristics

This study was conducted at eight sandy beach surf zones located in the Guayas and Santa Elena provinces in the central coast of Ecuador (Fig. 1). The Ecuadorian coast is located in a transition zone between the cold (<22 °C), high salinity (>35) Peru Current, which flows north from Peru and is present off the coast from July through October, and the warm (>25 °C), low salinity (<34) Panama Current, flowing south from Colombia and Panama during January through April (Cucalon, 1986, 1989; Montecino et al., 2005). These two currents influence the climate in coastal Ecuador producing a dry (mean precipitation: ~400 mm) and wet season (~1800 mm) when the Peru and Panama Current are present, respectively. These oceanic currents also affect

Fig. 1. Map of central coast of Ecuador with location of eight sandy beach surf zones sampled during 1999–2000. Also noted is the Guayas River, the largest estuarine system in western South America, the 200 m contour line, and an insert of South America indicating the location of the Ecuadorian coast.

the Ecuadorian coastal communities by importing fauna that is more common off Peru and Chile in the case of the Peru Current, and Panama and Colombia for the Panama Current (Cucalon, 1986, 1989; Montecino et al., 2005).

The Ecuadorian coast experiences a mixed, semidiurnal-dominant mesotidal regime, with a periodicity of 11.5–13.5 h and a 2.6 m mean tidal range. Waves are mostly from the northwest and their sizes vary with the season, with larger average wave height in the wet than dry season (Vera San Martin, 2000). The eight beaches are considered exposed to semi-exposed, low-tide terrace-rip beaches (McLachlan, 1980b; Short and Wright, 1983; Vanagt, 2007). These beaches were selected because of their distance from the Guayas River and the continental slope (Fig. 1, Table 1). The main economic activities that occur on these beaches is tourism and, with the exception of Salinas 1 and 2, artisanal fishing (Arriaga and Martinez, 2002).

2.2. Sampling methodology

We sampled the eight beaches (Fig. 1, Table S1) once every three months in August and November 1999, and February and May 2000 during spring low water tide. Samples taken during August represent the dry season, November samples are called Transition 1 Season, February samples were Wet season samples, and May represented the Transition 2 Season. The hyperbenthos was sampled using a hyperbenthic sledge (mouth: 0.50 × 0.70 m) with a cone-shaped net strapped to the back (4 m long, 1 mm mesh size). The mouth of the