Continental Shelf Research 137 (2017) 131–141

Contents lists available at ScienceDirect

Continental Shelf Research

journal homepage: www.elsevier.com/locate/csr

Abundance and size patterns of echinoderms in coastal soft-bottoms at Deception Island (South Shetland Islands, Antarctica)

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ARTICLE INFO

Keywords:
Benthic invertebrates
Brittle star
Sea urchin
Sea star
Sedimentation
Density

ABSTRACT

Deception Island is an active volcano in Antarctic waters under high sedimentation regimes, which may affect the abundance and structure of soft-bottom assemblages. During the summer of 2012–2013, a survey of the shallow water soft-bottom assemblages of Deception Island was carried out to examine patterns of abundance and size structure of the three dominant echinoderms (*Ophionotus victoriae*, *Sterechinus neumayeri* and *Odontaster validus*) at 8 locations encompassing a gradient in proximity from the open ocean, including two depths (5 *vs.* 15 m) per location. Abundance patterns of the three species varied with depth; organisms were typically more abundant at 15 relative to 5 m depth. Our results partially supported the hypothesis that echinoderms from locations adjacent to the open ocean present larger abundances. Body sizes varied significantly among locations and depths for the three species and some places presented a density-size pattern. High sedimentation rates, combined with low ice-related disturbance, may be the reason behind the large abundances of echinoderms found in this waters.

1. Introduction

The distribution of benthic organisms on the Antarctic continental shelf is highly variable across scales of spatial variation (Arntz et al., 1994; Barnes and Conlan, 2007; Gray, 2001; Gutt, 2000; Teixidó et al., 2004). This patchiness is probably related to the effects of ice disturbance at current timescales, through the actions of ice scouring and anchor ice formation (Brown et al., 2004; Dayton et al., 1969; Gutt and Piepenburg, 2003; Smale, 2007), as well as at evolutionary timescales, following the cyclical advance and retreat of the Antarctic ice sheet (Clarke et al., 1992; Clarke et al., 2004). These mechanisms of disturbance, in combination with other factors such as sedimentation, food availability and currents flow, have shaped a highly heterogeneous seascape. Coastal benthic communities of Antarctica are characterized by a high abundance and diversity of marine invertebrates (Dell, 1972; Arntz et al., 1994, 1997), and the dominance of suspension feeding organisms (Jażdżeski et al., 1986; Ramos, 1999). The most abundant invertebrates include soft corals, tunicates, and, especially, sponges and echinoderms (Dearborn, 1972; Dayton et al., 1974; White, 1984; Cattaneo-Vietti et al., 1999; Clarke and Johnston, 2003). Particularly, Antarctic echinoderms are important contributors to the overall benthic biomass and production, playing a significant role in the global marine carbon cycle (Lebrato et al., 2010). Furthermore, echinoderms easily add up to 45% of the overall abundance of the benthos (Moya et al., 2003), even reaching 98% of the total epifaunal community at 8–12 m depth in Whaler´s Bay, Deception Island (Barnes et al., 2008).

Deception Island (DI), one of the South Shetland islands located west of the Antarctic Peninsula, is part of an environment with low fluctuations in temperature and salinity (Arntz et al., 1994). Compared to nearby islands, DI is clearly depauperated in terms of fauna (Lovell and Trego, 2003). In fact, DI is a volcanically active island that has not erupted since 1970 (Elderfield, 1972); many taxa are still poorly represented, and the colonizers are mainly those with planktotrophic larvae (Barnes et al., 2008). The walls of the volcano are covered by pyroclastic ashes and lapilli-tuff, which are snow-covered from June through November. The transportation of sediment (lapilli-tuff) by winds, as well as the melting water forming into Port Foster, results in a relatively flat area of sand and silt across the caldera. The sediments of DI are similar to those of other South Shetland islands (Sáiz-Salinas et al., 1997), yet the benthic community may be different from those elsewhere. In 1964–65, the two most abundant epibenthic organisms were: *Ophionotus victoriae* and *Sterechinus neumayeri*; during the eruption of December 1967, however, their populations suffered from a mass mortality (Gallardo and Castillo, 1968). Between 1967 and 1981,

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http://dx.doi.org/10.1016/j.csr.2016.12.010
Received 12 June 2016; Received in revised form 18 December 2016; Accepted 19 December 2016
Available online 04 January 2017

the epibenthic megafaunal community recovered to its pre-eruption conditions, with the return of *Ophionotus victoriae, Sterechinus neumayeri* and *Odontaster validus* (Retamal et al., 1982). Subsequent studies confirmed that epibenthic assemblages remained stable, with the continued dominance of *O. victoriae*, and remarkable low abundances of sessile organisms associated to soft-bottoms (Cranmer et al., 2003; Lovell and Trego, 2003; Barnes et al., 2008). According to the literature, suspension-feeders are very scarce in DI, where ascidians characterize the filter-feeding community (Arnaud et al., 1998).

Three species of echinoderms, generally occurring together, reach high values of abundance at DI: the ophiuroid *Ophionotus victoriae* Bell 1902 (Cranmer et al., 2003), the echinoid *Sterechinus neumayeri* and the asteroid *Odontaster validus* (Koehler, 1912). *O. victoriae* is an opportunistic generalist with high diet plasticity, feeding on 13 different phyla including krill (Dearborn, 1977; Fratt and Dearborn, 1984; Pawson, 1994) but mainly detritivore. It is extremely common along the Antarctic Peninsula. This species inhabits a variety of substrates at depths ranging from 5 to 1266 m (Madsen, 1967). *S. neumayeri* is the most abundant sea urchin in shallow Antarctic waters and occurs on gravel and rocks down to 500 m water depth (Brey and Gutt, 1991). They feed mainly on benthic diatoms as well on red algae and seal faeces (Dearborn, 1965; Pearse and Giese, 1966; McClintock, 1994). The sea star *O. validus* is abundant and widely distributed in most of the shallow benthic environments surrounding the Antarctic continent (Dearborn, 1965; McClintock et al., 1988), being most common between 15 and 200 m depth (Dearborn, 1977). *O. validus* has an opportunistic behavior and a variable diet; it may act as a suspension feeder, as an herbivore, as a scavenger, and as an active predator (Dearborn, 1977; Dayton, 1974; Pearse, 1964; Peckham, 1964).

Although the benthic community of DI has been studied on several occasions, it is not known if the abundance and distribution of epibenthic megafauna vary spatially. The aim of this study was to examine patterns of abundance, distribution and size structure of three dominant benthic echinoderms (*Ophionotus victoriae*, *Sterechinus neumayeri* and *Odontaster validus*) at shallow coastal waters. The sampling was designed to cover two depths (5 and 15 m) at each of 8 locations along the bay, which encompasses a gradient in proximity from the open ocean. We hypothesized that there would be differences in the abundance, distribution and size structure of each species between both depths and among locations, due to varying environmental conditions with varying proximity from the entrance of the bay.

2. Material and methods

2.1. Study area

During January 2013, the abundances and size structure of the three dominant soft-bottom echinoderms (*Ophionotus victoriae*, *Sterechinus neumayeri* and *Odontaster validus*) were determined, through SCUBA diving, at eight locations along Port Foster, inside the caldera of DI, South Shetland Island, Antarctica (Fig. 1, Table 1). This area is typically covered by ice, for at least seven months every year. The water temperature at 15 m depth ranges from 0° to 2 °C, and the primary production is highly seasonal (Smith et al., 2003). The water column is stratified in the warmer months (Lenn et al., 2003), followed by mixing during the austral winter months (June-October) (Glatts et al., 2003). The locations, in order of increasing distance from the open sea, were assigned to three groups: (i) outer group; Whaler's Bay South (WB-S), Whaler's Bay North (WB-N), (ii) intermediate group; Bidones Point East (BID-E), Bidones Point West (BID-W), and Spanish Antarctic Base (BAE; in front of the *Gabriel de Castilla* Antarctic Base), and (iii) inner group; Fumarole Bay (FUM), Telephone Bay (TEL; area recently opened to Port Foster), and Pendulum Cove (PEN; an area with abnormal water temperature due to an hydrothermal vent) (Somoza et al., 2004). At each location, two depths (5 and 15 m) were surveyed. Port Foster is very steep all along the bay with a sheltered platform down to ca. 4–6 m depth; below this platform, the slope increases dramatically reaching rapidly depths of ca. 100 m.

2.2. Sampling design and biotic measurements

Three replicated transects were carried out at each location. Transects were 5–10 m apart and ran along a depth gradient from 15 to 5 m depth. Along each transect line, we counted the number of specimens of the three species by recording, every 0.5 m, the organisms laying under the transect line (line-intercept transect, LIT). In addition, at each of two depth strata (5 and 15 m) per location, six replicated quadrats (0.5 m×0.5 m) were randomly deployed, and specimens inside counted. When possible, 60 organisms per species and depth were collected, all of which were measured (disk diameter for the brittle star, body diameter for the sea urchin and body length for the sea star) and weighted (wet weight), before being returned to the sea.

2.3. Abiotic measurements

Three replicated 10 cm diameter (0.008 m^2) cores were taken at each depth and location, which penetrated approximately 10 cm into the sediment. Sub-samples were analyzed for grain size, the degree of sorting and the content of organic matter. Organic matter content was calculated after drying each sediment sample for 72 h at 60 °C and subsequently calcinating the sample with a muffle furnace at 550 °C for 10 h. The percentage of organic matter was then calculated using the difference in weight before and after calcination. To assess the grain size and the degree of sorting, sediments were initially treated with 1 M hydrochloric acid to remove carbonates before combustion. Sediment grain size was obtained by calculating the mean and standard deviation from cumulative plots along a phi scale, analyzed on a Beckman-Coulter LS 13 320 Laser Diffraction Particle Size Analyzer. The degree of sorting was expressed as: $\varphi = -log_2\, D/D_O$ (Krumbein, 1934), where D is the diameter of the particle and D_O is a reference diameter, equal to 1 mm (to make the equation dimensionally consistent). Unfortunately, sediment samples from Whalers Bay South (5 m depth) were lost, and data could not be determined for this location.

2.4. Statistical analyses

To test for differences in the abundances (ind m^{-2}) of each echinoderm from deployed quadrats at each depth strata and location, a two-way analysis of variance (ANOVA) including `*depth*´ as a fixed factor and `*location*´ as a random factor, was performed (Zar, 1984) for each species. In case of significant *'depthxlocation'* interactions, pair wise tests between `*depth*´ levels were performed separately for each location. Abundance data were fourth root-transformed prior to each analysis to avoid heterogeneous variances. We omitted Pendulum Cove from the analysis, due to the absence of any organism. To work out the influence of environmental drivers on patterns of echinoderm abundances, a generalized linear model (GLM) was performed for each species. Environmental (quantitative) drivers were included, as well as depth and the distance from the entrance of channel, to predict abundances. To determine the degree to which echinoderm populations were clumped, uniformly or randomly distributed, the coefficient of variation (standard deviation/mean) of each species were calculated. Finally, data from the three transects per location were pooled for each 0.5 m interval; a simple linear regression was then adjusted to predict echinoderm abundances according to depth for each location. Differences in the frequency of sizes of each specie between the two depths were statistically tested through a *chi-square* test for each location.