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A glimpse into the deep of the Antarctic Polar Front – Diversity and abundance of abyssal molluscs

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ABSTRACT

Our knowledge of the biodiversity and distribution patterns of benthic deep-sea faunas is still limited, with large parts of the world's abyss unexplored, lacking α-taxonomic data across oceans basins and especially of biogeographic transition zones between oceans. The Antarctic Polar Frontal Zone has been discussed as major biogeographic barrier hindering faunal exchange between Subantarctic and Antarctic provinces and conserving high rates of endemism in the Southern Ocean benthos. In the present study we report first, exploratory α-taxonomy on the malacofauna sampled by means of an epibenthic sledge from four bathyal respectively abyssal stations (2732–4327 m depth) in the vicinity of the Antarctic Polar Front during the SYSTCO II expedition (SYSTem COupling in the Southern Ocean, RV Polarstern cruise ANT XXVIII/3). We identified 58 distinct molluscan taxa based on external morphology ('morphospecies'); of the 33 taxa successfully assigned to described species 94% were previously reported from the Southern Ocean, but 24% exhibit distribution ranges crossing the Polar Front. One North Atlantic scaphopod is reported for the first time in Antarctic waters. Our study supports that the Antarctic Polar Front does not serve as effective barrier preventing gene flow in deep-sea molluscs. The present dataset shows the general characteristics of deep-sea sampling: patchiness in distribution and a high degree of singletons. Overall molluscan abundances were generally low ranging between 3.60 and 24.65 ind./1000 m², but in comparison with equatorial and subtropic abyssal basins, gastropod species richness and abundance were reaching high values similar to high Antarctic stations. Comparison between high productivity and low productivity zones along the Polar Front suggests increased abundances and species richness in high productivity zones. Intensified sampling is needed, however, to outweigh stochastic errors and to evaluate the influence of carbon flux as driving factor to faunal composition and abundances of abyssal molluscs.

1. Introduction

Knowledge on the diversity of deep-sea benthos is still scarce and overall biodiversity assessments are complicated by many 'white spots' of unsampled abyssal regions and the uneven distribution of sampling efforts. First studies on the Antarctic abyssal benthos have revealed stunning species richness (Brandt et al., 2007a, 2007b), opposing previous hypotheses on impoverished deep-sea fauna along latitudinal gradients towards the poles (e.g., Poore and Wilson, 1993; Rex et al., 1993). Equatorial to subtropical south-eastern Atlantic deep-sea basins sampled during DIVA expeditions on the other hand revealed considerably poorer abyssal communities in terms of species richness and abundances (Schrödl et al., 2011). Representing the geographic transition zone between Antarctic waters from the south and Subantarctic Atlantic waters from the north, the Antarctic Polar Frontal Zone is of high faunal interest for a better understanding of the colonization of the comparably species rich Southern Ocean and the faunal exchange between Subantarctic and high Antarctic provinces. Large parts of the benthic marine fauna of Antarctica is considered as endemic, ranging in estimations of around 50% endemics across molluscan taxa (Cepalopoda 54%, Bivalvia 43%, and Gastropoda 74%) (Griffiths et al., 2009). These numbers are likely to even increase when molecular methods start to be included to uncover cryptic lineages (Griffiths, 2010; Kaiser et al., 2013). Concerning the recorded high degree of endemism in the benthic Antarctic fauna, the Antarctic Polar Front has been discussed as biogeographic barrier hindering species migration in and out of the Southern Ocean due to the strong current system and a high surface temperature gradient

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(Griffiths, 2010; Rogers, 2007). All but a single Antarctic deep-sea gastropods were reported to be endemic (Schrödl et al., 2011; Schwabe et al., 2007), suggesting that barriers may exist even for the abyssal fauna. So far no α-taxonomic exploration has taken place in order to sample the abyssal plains along the Polar Front and the few recent sampling efforts are restricted to shelf areas of the isolate Bouvet Island (Arntz et al., 2006; Linse, 2006) or South Georgia (e.g., Hogg et al., 2011) slightly south of the Antarctic convergence.

Due to strong upwelling of nutrient-rich deep water, the Antarctic Polar Frontal Zone is a region characterized by elevated primary production (Moore and Abbott, 2000; Sokolov and Rintoul, 2007) and data retrieved from sediment traps indicate the highest carbon fluxes (3.7–3.9% of primary production) of the Southern Ocean (Fischer et al., 2000). Deep-sea communities are generally considered as strongly food-limited biota, with faunal composition, species richness and abundance of specimens being highly dependent on the organic carbon fluxes reaching the sea floor (Ramirez-Llodra et al., 2010; Smith et al., 2008). One of the major aims of the SYSTCO project (SYSTem COupling in the Southern Ocean) is to evaluate the impact of seasonal to long-term changes in the primary production in surface waters on the faunal composition and abundances of abyssal benthos (Brandt et al., 2011b). We conducted seven epibenthic sledge (EBS) deployments at four stations along or slightly south of the Polar Front in the course of the SYSTCO II expedition on board of RV Polarstern (cruise ANT XXVIII/3). All deployments took place in the *Fragilariopsis kerguelensis*-dominated primary production regime (Sachs et al., 2009), but varied between long-term low vs. high surface productivity estimated from integrated GlobColor satellite data of surface Chlorophyll- *a* (see Brandt et al.,).

The present survey provides an initial assessment of the largely unknown benthic abyssal malacofauna beneath the Antarctic Polar Front. We provide first α-taxonomic data on species richness and abundances of molluscs for future evaluation on the importance of the Antarctic Polar Front as biogeographic barrier promoting endemism in the Southern Ocean. Despite the typical limitations of exploratory studies and confronted with putative scattered distributions and rarity, we discuss first trends on the faunal composition of abyssal molluscs among stations and briefly compare regions of different surface productivity.

2. Material and methods

Benthic samples were taken by means of an Brenke-EBS (Brenke, 2005) at seven different deep-sea collecting sites (corresponding to four stations) roughly along and south of the Polar Front (Fig. 1) from board of R.V. *Polarstern* during the SYSTCO II (ANT XXVIII-3) cruise in January–February 2012. Details on the localities of the EBS deployments and the depth of the bathyal and abyssal sampling sites are given in Table 1. All EBS deployments were located in the *F. kerguelensis*-dominated primary production regime (see Sachs et al., 2009 for regimes). Average Chlorophyll-*a* (Chl *a*) concentrations based on satellite images in the sampling months January to February 2012 indicate low surface productivity (below 0.5 mg m^{-3}) at station 81 (with two repeated deployments 81-17, 81-18), station 84 (one deployment 84-25) and station 85 (one deployment 85-15) whereas station 86 (three deployments 86-20, 86-24, 86-25) was characterized by high surface productivity (above 1.0 mg m^{-3} – see Brandt et al., 2014b).

The EBS is equipped with two boxes (epi- and suprabenthic sampler) with an opening of 0.35 m^2 each leading into 500 μm mesh-sized nets, which terminate in 300 μm mesh-sized cod ends. Trawling distances of the deployments (calculated after equation '2' in Brenke (2005)) ranged between 2586 and 4789 m (Table 1). An EBS deployment was considered successful when cod ends contained abyssal fauna. In the water column, the net boxes are closed to prevent mixture with pelagic fauna and putative loss of benthic faunal components. On deck, the content of the cod ends of epi- and supranet as well as the supernatants from the nets were separately collected and immediately fixed in pre-cooled 96% ethanol. Samples were then stored for a minimum of 48 hours at −20 °C and the ethanol was exchanged twice every 24 h.

All EBS samples of the SYSTCO II cruise were presorted to phyla level on board and at the German Centre for Marine Biodiversity Research (DZMB, Hamburg, Germany). The collected specimens of molluscs were later identified at the SNSB-Bavarian State Collection

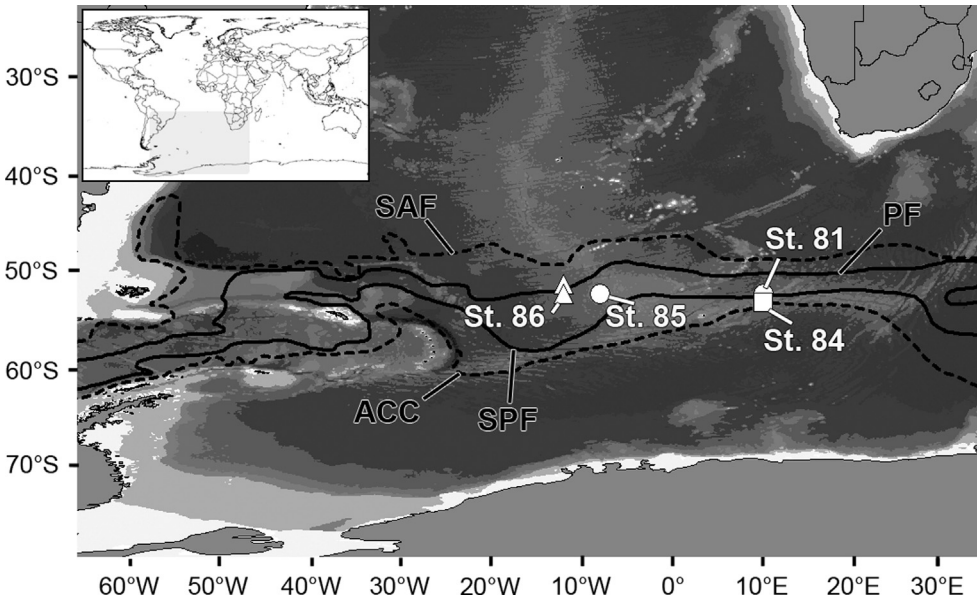

Fig. 1. Map of the sampling area showing different stations of EBS deployments analyzed in the present study and the main oceanographic fronts based on Orsi et al. (1995). ACC – Southern boundary of the Antarctic Circumpolar Current, PF – Polar Front, SAF – Subantarctic Front, SPF – Southern Polar Front after Read et al. (1995) (refers to sACCf Southern Antarctic Circumpolar Current Front in Orsi et al,. 1995).