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Microzooplankton community composition along the Western Antarctic Peninsula

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ABSTRACT

Microzooplankton are an integral part of aquatic food webs, yet compared to macrozooplankton, are understudied in the Southern Ocean. The region along the Western Antarctic Peninsula (WAP) is experiencing rapid climate warming, resulting in declines in sea ice extent and duration, and affecting the marine food web. Microzooplankton community structure along the WAP was analyzed in January 2010 and 2011 as part of the Palmer Antarctica Long-Term Ecological Research project. Whole seawater samples were collected within the top 100 m of the water column along both north-south and coastal-offshore gradients, and major taxa of microzooplankton were quantified using microscopy. Average chlorophyll-*a* concentrations and microzooplankton biomass were higher in 2011 compared to 2010. Athecate dinoflagellates and aloricate ciliates dominated microzooplankton biomass, and the biomass of most taxonomic groups was higher in the south compared to the north. Specifically, aloricate ciliate and tintinnid biomass increased with increasing latitude, and biomass peaked at several southern, inshore stations – including Marguerite Bay, which was an area of high biomass for some microzooplankton taxa. Biomass was higher in surface waters compared to 100 m, and variability in microzooplankton biomass between years and with distance from shore was most likely due to sea ice dynamics. Microzooplankton biomass was positively correlated with chlorophyll-*a* and particulate organic carbon. These results are used to consider how microzooplankton populations may be adjusting to environmental changes along the WAP.

1. Introduction

The importance of microzooplankton in marine food webs as grazers (Pace, 1988; Calbet and Landry, 2004), food for higher trophic levels (Stoecker and Capuzzo, 1990; Fessenden and Cowles, 1994; Froneman et al., 1996; Schmidt et al., 2006), and recyclers of nutrients (Andersen et al., 1986; Sherr and Sherr, 2002) is now widely recognized. However, in the Southern Ocean where the majority of food web studies have focused on the abundance, distribution, and grazing of krill and other macrozooplankton (Quetin et al., 1996; Dubischar and Bathmann, 1997; Pakhomov et al., 1997; Ross et al., 2008), the role of smaller consumers (e.g., phagotrophic protozoans $<200\ \mu m$) is poorly defined. It is particularly important in an era of rapid environmental change to determine a reference point of species abundance and distribution, particularly in regions where such changes are likely to be pronounced (Smith et al., 1999).

The Western Antarctic Peninsula (WAP) is a region currently experiencing one of the fastest rates of warming on Earth, with an increase in average winter air temperature of approximately 1 °C per decade since 1950 (Smith et al., 1996; Vaughan et al., 2003; Ducklow et al., 2012). Concurrently, the ocean heat content over the continental shelf in this region has steadily increased since 1993, due to the warming and upwelling of Upper Circumpolar Deep Water (UCDW) onto the shelf (Martinson et al., 2008; Martinson and McKee, 2012). This is the primary mechanism for sea ice and glacial melt along the WAP (Ducklow et al., 2012), and, coupled with atmospheric variables, has caused a decrease in sea ice extent and a change in the timing of sea ice advance and retreat (Stammerjohn et al., 2008a). This regional warming has differentially affected the WAP, with a warmer, sub-Antarctic climate invading the northern part of the Peninsula and replacing the typical cold, dry Antarctic climate still present in the southern part of the Peninsula (Smith et al., 1999; Ducklow et al., 2012).

Phytoplankton have been responding to these long-term changes in air temperature and sea-ice dynamics along the WAP (Montes-Hugo et al., 2009), and shifts in phytoplankton could affect the distribution and community composition of microzooplankton, as well as higher trophic levels that feed on them. Less sea ice cover and stronger winds (leading to deeper mixing and

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light limitation for phytoplankton) in the northern WAP has led to a decrease in chlorophyll concentrations and average phytoplankton size. In contrast, the decrease in sea ice in the southern WAP, which was previously permanently ice covered, has released phytoplankton from light limitation and caused an increase in phytoplankton biomass (Montes-Hugo et al., 2009). This change in chlorophyll-*a* distribution along the WAP has been accompanied by shifts in phytoplankton composition, where assemblages in the north are dominated by smaller phytoplankton while those in the south have a greater fraction of diatoms and larger cells (Montes-Hugo et al., 2009).

In the Southern Ocean microzooplankton can be as abundant as they are in other regions of the world, and exhibit distinct seasonality and extreme patchiness (Garrison, 1991a; Umani et al., 1998; Landry et al., 2002). Microzooplankton abundance is often correlated with chlorophyll-*a* and particulate organic carbon (POC), indicating an influence of food supply on their distribution (Heinbokel and Coats, 1986; Burkill et al., 1995; Archer et al., 1996; Becquevort, 1997; Klaas, 2001). Studies quantifying microzooplankton structure in the Southern Ocean indicate that the dominant microzooplankton can change dramatically along a transect (Alder and Boltovskoy, 1993), with some changes associated with different water masses (Burkill et al., 1995; Safi et al., 2007). Only two studies have described microzooplankton along the WAP. Calbet et al. (2005) found that the assemblage was dominated by aloricate ciliates, and that dinoflagellate abundance (represented by the genus *Gyrodinium*) was one order of magnitude lower than that of ciliates. Also, ciliate abundances peaked between 40 and 80 m and coincided with high ammonium concentrations, while dinoflagellates had a more homogeneous depth distribution (Calbet et al., 2005). Alder and Boltovskoy (1991) found that microzooplankton, especially tintinnids, appeared to be associated with sea ice along the WAP. Tintinnids and dinoflagellates were tightly correlated with each other, with highest abundances occurring in the southern Bellingshausen Sea near the coast (Alder and Boltovskoy 1991).

This study provides an extensive description of microzooplankton community structure in the WAP in January of two contrasting years along both north–south and coastal–offshore gradients, which is needed to better understand the factors that affect their abundance and distribution. Most importantly, these results provide a reference point for quantifying how future changes in this rapidly-warming region might affect microzooplankton community structure and WAP food web dynamics.

2. Methods

2.1. Study site

As part of the Palmer Antarctica Long-Term Ecological Research (PAL LTER) project, microzooplankton samples were collected on annual research cruises aboard the ARSV *Laurence M. Gould* in January 2010 and 2011. The PAL LTER sampling grid area along the WAP extends from Palmer Station on Anvers Island (64.77°S, 64.05°W) south to Charcot Island (69.45°S, 75.15°W) and from coastal waters to approximately 200 km offshore (Ducklow et al., 2007, 2012). Water samples for microzooplankton analysis were collected at select stations on this sampling grid (Fig. 1).

2.2. Sample collection

For the purposes of this study, we only considered single-celled protozoa (i.e., phagotrophic dinoflagellates and ciliates) because tiny larval stages of metazoans (i.e., copepod nauplii), which are also considered microzooplankton (operationally defined as

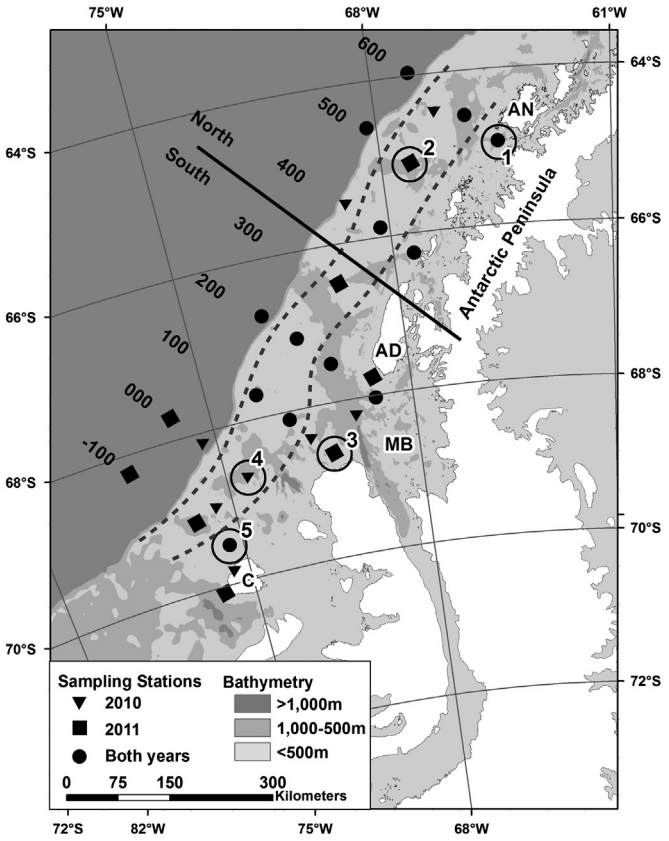

Fig. 1. Map of the Palmer Antarctica Long-Term Ecological Research study region where whole water samples were collected for microzooplankton community composition in 2010 and 2011. AN: Anvers Island, AD: Adelaide Island, MB: Marguerite Bay, C: Charcot Island. LTER grid lines are numbered (600 to −100; referred to in Fig. 11). Palmer Station is located on Anvers Island. The Palmer Deep canyon is located just south of Anvers Island, and the Marguerite Trough is located just south of Adelaide Island. A solid line separates the northern and southern subregions. Inshore, midshelf, and offshore regions are separated by dashed lines. All region divisions are based on hydrographic and sea-ice conditions (Martinson et al., 2008; Stammerjohn et al., 2008a). Select stations of interest referred to in the text are circled and numbered. The continental shelf is about 200 km wide and averages 430 m in depth. Canyons cut the shelf and can approach depths of 1,000 m. The light/dark gray interface indicates the shelf break to waters ~3000 m deep (Ducklow et al., 2012).

phagotrophic organisms 20–200 μm), were often much larger than 200 μm and not abundant. Thus the term 'microzooplankton' will hereafter be used to describe single-celled phagotrophic protists whose sizes ranged from 20–200 μm. A few microzooplankton groups were slightly smaller (e.g., some dinoflagellates) or larger (e.g., *Laackmaniella* spp., *Protoperidinium antarcticum*) and were included in this analysis. Larger, rarer protozooplankton (i.e., foraminifera, acantharia, and radiolaria), present in net-collected (64 μm mesh) samples in a companion study, are not considered.

To enumerate microzooplankton, whole water samples were collected using 12 L Niskin bottles mounted on a CTD rosette at three depths: surface (10 m), subsurface chlorophyll-*a* maximum (as determined by in situ fluorescence, see Tables S1 and S2 for depth), and deep (100 m). Fluorescence measured in situ was significantly positively correlated with extracted chlorophyll-*a* ($p < 0.001$, data courtesy of O. Schofield and D. Martinson). For each depth, 200–250 ml whole seawater was preserved with acid Lugol's (final concentration 6–8%) and stored in the dark at room temperature up to 12 weeks or refrigerated at +4 °C for up to one year until sample processing in our laboratory at the Virginia Institute of Marine Science. Although acid Lugol's (high concentrations, ~10%) is among the best solutions for preserving microzooplankton such as ciliates, cell losses still likely occurred (Stoecker et al., 1994).