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Community structure and benthic habitats across the George V Shelf, East Antarctica: Trends through space and time

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A B S T R A C T

Physical and biological characteristics of benthic communities are analysed from underwater video footage collected across the George V Shelf during the 2007/2008 CEAMARC voyage. Benthic habitats are strongly structured by physical processes operating over a range of temporal and spatial scales. Iceberg scouring recurs over timescales of years to centuries along shallower parts of the shelf, creating communities in various stages of maturity and recolonisation. Upwelling of modified circumpolar deep water (MCDW) onto the outer shelf and cross-shelf flow of high-salinity shelf water (HSSW) create spatial contrasts in nutrient and sediment supply, which are largely reflected in the distribution of deposit- and filter-feeding communities. Long-term cycles in the advance and retreat of icesheets (over millennial scales) and subsequent focussing of sediments in troughs such as the Mertz Drift create patches of consolidated and soft sediments, which also provide distinct habitats for colonisation by different biota. These physical processes of iceberg scouring, current regimes and depositional environments, in addition to water depth, are important factors in the structure of benthic communities across the George V Shelf. The modern shelf communities mapped in this study largely represent colonisation over the past 8000–12,000 years, following retreat of the icesheet and glaciers at the end of the last glaciation. Recolonisation on this shelf may have occurred from two sources: deep-sea environments and possible shelf refugia on the Mertz and Adélie Banks. However, any open-shelf area would have been subject to intense iceberg scouring. Understanding the timescales over which shelf communities have evolved and the physical factors which shape them will allow better prediction of the distribution of Antarctic shelf communities and their vulnerability to change. This knowledge can aid better management regimes for the Antarctic margin.

1. Introduction

Establishing the relationship between abiotic factors and biological assemblages can be applied as an important tool for mapping marine bioregions. Around much of the Antarctic margin there are major gaps in our understanding of the distribution and diversity of the benthic biota, which makes it difficult to manage the marine environment in a consistent manner. Applying physical parameters to map benthic communities has the advantage that many variables, such as seafloor bathymetry and oceanographic properties, can be measured relatively easily and consistently across broad areas allowing more comprehensive mapping of bioregions. The application of physical surrogates to map the distribution of biota is being increasingly incorporated in marine management approaches in many countries (Greene et al., 1995; Harris et al., 2007; Hockey and Branch, 1997; Pickrill and Todd, 2003) and has already been successfully applied in mapping the distribution of benthic biota on the Antarctic shelf (Barry et al., 2003; Beaman and Harris, 2005; Johst et al., 2006; Potthoff et al., 2006; Teixidó et al., 2002; Thrush et al., 2006) and slope (Post et al., 2010). This approach can therefore aid more rigorous designation of marine protected areas (MPAs) and the identification of vulnerable marine ecosystems (VMEs) (e.g., Post et al., 2010).

The extensive biological and physical datasets collected during fieldwork conducted as part of the Census of Antarctic Marine Life (CAML) provides the opportunity to explore bio-physical relationships around the Antarctic margin. The Collaborative East Antarctic Marine Census (CEAMARC) survey from December 2007 to January 2008 was conducted on the George V

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Shelf, East Antarctica, and collected an array of underwater video footage in addition to physical data such as sedimentary and oceanographic datasets. Analysis of these datasets in this study allows bio-physical relationships to be tested across this shelf, building on the work of Beaman and Harris (2005). We analyse the data at regional (between sites) and local (within transects) scales to explore the processes that may influence the benthic taxa at varying spatial scales. We also consider the influence of processes operating over a range of temporal scales, ranging from the decadal to centennial scales of iceberg scouring to the millennial scale of glacial cycles, to better understand patterns of recolonisation.

2. Background

2.1. Morphology of George V Shelf

The George V Shelf is deep, with an average depth along the shelf break of 500 m (Fig. 1). The main bathymetric features of the shelf are the George V Basin, which reaches depths of 1300 m adjacent to the Mertz Glacier Tongue, and the Adélie and Mertz Banks, which have mean depths of approximately 200–250 m. The inner shelf is cut by a complex series of deep (up to ~1200 m) depressions and small glacial basins. Large submarine canyons cut the continental slope, with the Cuvier and Jussieu Canyons reaching the shelf break.

Iceberg scours on the George V Shelf have been found to depths of at least 500 m on Mertz Bank (Barnes and Lien, 1988). Grounded icebergs on the George V Shelf are sourced from the Ross Ice Shelf, the Ninnis Glacier and the Cook Ice Shelf and advected westwards via the westwind drift (Massom, 2003). While icebergs produced by the Mertz Glacier have relatively small draft (maximum keel depth of 298 m) and are therefore less likely to ground, those from the Cook Ice Shelf have keel depths of up to 521 m (Dowdeswell and Bamber, 2007), so ground readily on the relatively shallow margins of the Mertz and Adélie Banks.

2.2. Oceanography of George V Shelf

The occurrence of the Mertz Polynya, an area of ice-free water, dominates the oceanography of the George V Shelf (Fig. 1). The polynya is sustained by strong and persistent katabatic winds that drain into Buchanan Bay, producing rapid rates of sea-ice formation and removal in the nearshore (Massom et al., 2001). The northward extension of the Mertz Glacier Tongue by grounded icebergs and fast-ice blocks the westward advection of sea-ice into the polynya area. The broader extent of the polynya away from coastal bays is also influenced by the passage of synoptic weather systems. Sustained sea-ice production between April and September in the polynya region increases shelf water salinity and density (Williams et al., 2008), forming high salinity shelf water (HSSW) (Bindoff et al., 2000).

Upwelling of modified circumpolar deep water (MCDW) onto the shelf between November and March via the Adélie Sill (Bindoff et al., 2000; Rintoul, 1998; Williams et al., 2008, Fig. 1), combined with the input of cool, fresh ice shelf water, plays an important role in the formation of Adélie land bottom water (ALBW). MCDW is relatively warm and therefore provides extra heat that promotes melting of sea-ice in the polynya region, enhancing the overall size of the polynya (Rintoul, 1998). Furthermore, MCDW increases the salinity of the shelf waters. Mixing between HSSW and MCDW raises the salinity of the shelf waters to the point where it is dense enough to spill over the Adélie Sill as ALBW. ALBW is found along the continental slope west of the Adélie Sill. For water mass properties see Bindoff et al. (2000, 2001).

2.3. Biological production on George V Shelf

The ice-free waters of coastal polynyas support a relatively long growing season, with phytoplankton production commencing soon after the spring equinox (Sambrotto et al., 2003). These waters therefore have high productivity compared to shelf areas

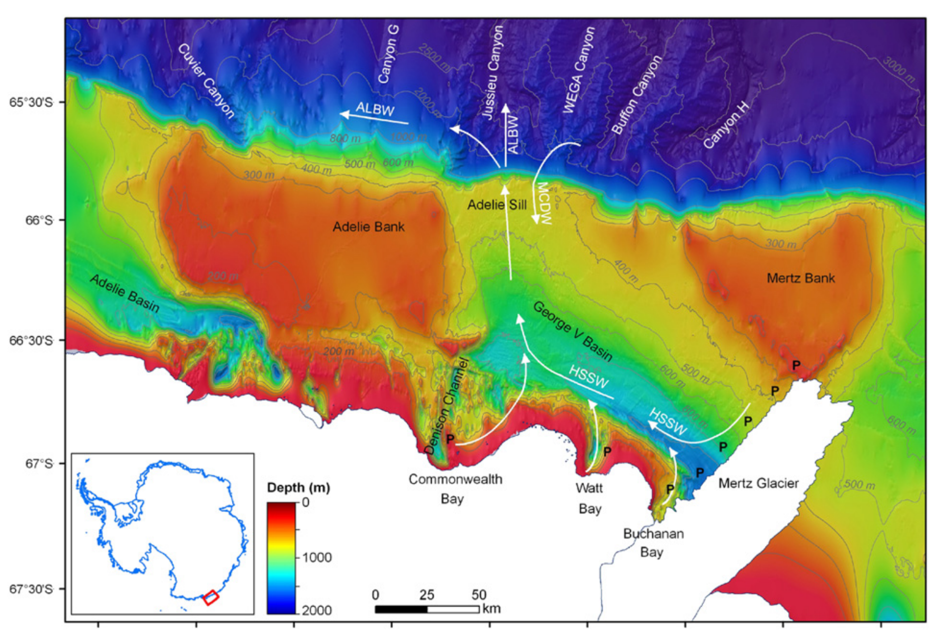

Fig. 1. Bathymetry and simplified bottom circulation over the George V Shelf. The bathymetry grid has a 250 m grid pixel resolution over the shelf (Beaman, 2008) and oceanographic circulation is based on (Rintoul, 1998; Bindoff et al., 2000; Massom et al., 2001). HSSW is high salinity shelf water, MCDW is modified circumpolar deep water and ALBW is Adélie land bottom water. **P** marks the extent of the Mertz Polynya along the coast and western edge of the Mertz Ice Tongue.