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Editorial

Introduction to understanding the linkages between Antarctic food webs and the environment: A synthesis of Southern Ocean GLOBEC studies

The Southern Ocean Global Ocean Ecosystems Dynamics (SO GLOBEC) Program was an international multidisciplinary effort designed to provide understanding of the physical and biological factors that influence growth, reproduction, recruitment, and overwintering survival of Antarctic krill (*Euphausia superba*), a key species in the Antarctic food web. The program was unique in its end-to-end food web approach that included predators and competitors of Antarctic krill, as well as the influence of habitat. Important target species at all trophic levels, including other zooplankton, fishes, penguins, seals, and cetaceans, were the focus of extensive ecological and physiological studies that were coincident with studies of habitat structure. The multi-trophic level approach adopted by the international scientific community integrated SO GLOBEC studies in the western Antarctic Peninsula (WAP) region (United States program), east Antarctica (Australian program), the Lazarev Sea (German program), and South Georgia (United Kingdom program). Similar studies in a range of habitats allowed regional comparisons, a main objective of the International SO GLOBEC program.

The SO GLOBEC program has provided new insights into the functioning of the Antarctic marine food web, especially in the winter. The first SO GLOBEC *Deep-Sea Research II* volume (Hofmann et al., 2004) presented initial results that highlighted the (1) role of hydrographic structure, circulation, and sea ice in structuring biological distributions in the western Antarctic Peninsula region, (2) behavior, growth, feeding, nutrition, and overwintering strategies of Antarctic krill, and (3) the distribution and abundance of fish, seabirds, seal, and cetaceans. The second SO GLOBEC *Deep-Sea Research II* volume (Hofmann et al., 2008) extended these results to provide correlations of biological patterns with habitat features, quantification of distributions of Antarctic krill and its predators, and understanding of relationships between predators, from fish to seals, to habitat structure, and prey availability. Many of those studies provide the first winter observations of predator condition, distribution, and habitat use in the WAP region.

The papers in this third *Deep-Sea Research II* volume continue the synthesis and integration of the SO GLOBEC data sets, with a focus on comparative studies within and between regions. Numerical circulation model studies of Circumpolar Deep Water intrusions on the western Antarctic Peninsula and in the Ross Sea showed differences in vertical mixing of this water mass that has implications for different basal melting rates of ice shelves and nutrient supply in the two regions (Dinniman et al., 2011). Numerical Lagrangian particle tracking studies showed the importance of the circulation in determining shelf residence times of water and biota, transport pathways, and retention regions giving rise to biological hot spots for the western Antarctic Peninsula (Piñones et al., 2011; Wiebe et al., 2011) and South Georgia (Young et al., 2011). Interannual variability in sea ice was documented and related to differences in wind conditions (Hyatt et al., 2011). The upper ocean properties around the South Orkney Islands, including sea ice production, were determined from a time series acquired by a southern elephant seal (*Mirounga leonine*) that was outfitted with a conductivity–temperature–depth satellite-data relay logger (Meredith et al., 2011). Such tagged animals were an integral part of several SO GLOBEC studies and build upon studies with instrumented crabeater seals (*Lobodon carcinophagus*) done along the WAP (Costa et al., 2008).

The data sets collected during the U.S. SO GLOBEC field program resulted in a first description and quantification of the distribution of invertebrate micronekton and macrozooplankton on the western Antarctic Peninsula continental shelf (Parker et al., 2011), which builds on a companion fish study (Donnelly and Torres, 2008) and provides a basis for comparisons to other regions of the Antarctic (Hunt et al., 2011). Zooplankton abundance, distribution, and habitat partitioning have been described and their bi-annual variability determined for the Marguerite Bay region of the WAP shelf (Marrari et al., 2011-a, 2011-b; Wiebe et al., 2011). The vertical and horizontal distributions of euphausiid species have been quantified and examined with numerical Lagrangian particle tracking simulations (Piñones et al., 2011; Wiebe et al., 2011). Quantification of genetic variation in Antarctic krill populations along the western Antarctic Peninsula supported local production as well as advective transport and production from outside the region (Batta-Lona et al., 2011).

Data sets from the German SO GLOBEC program allowed description of the seasonal variability in the macrozooplankton community of the Lazarev Sea (Hunt et al., 2011). Comparisons of the different seasons showed that this system shifts from top-down to bottom-up control from winter to summer. Similarly, the seasonal changes in pelagic tunicates in the Lazarev Sea suggested the importance of advective flows for maintenance of the observed distributions (Pakhomov et al., 2011).

The importance of temperature in general and Circumpolar Deep Water, particularly in structuring coastal Antarctic fish communities, was illustrated by a study of the presence/absence of antifreeze glycoproteins in the blood of several species of fish caught on the western Antarctic Peninsula continental shelf (Cullins et al., 2011). The end-to-end food web focus of the SO GLOBEC studies is reflected in the synthesis of the predator data

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sets (Ribic et al., 2011). Correlations between seabird community structure and environmental features (e.g., fronts, sea ice, etc.) in the western Antarctic Peninsula region were placed in the context of an Antarctic-wide seabird data synthesis. The winter foraging distribution of Adélie penguins (*Pygoscelis adeliae*) was related to habitat structure and found to differ for male and female birds (Erdmann et al., 2011). Sympatric krill predators (crabeater seals, minke whales, humpback whales, etc.) in the Marguerite Bay region appear to have little niche overlap (Friedlaender et al., 2011). Habitat preferences of blue whales (*Balaenoptera musculus*) were determined from data sets obtained from passive acoustic arrays deployed along the western Antarctic Peninsula during the U.S. SO GLOBEC field studies (Širovic and Hildebrand, 2011).

The SO GLOBEC synthesis and comparative studies are leading to revisions in our understanding of Antarctic food webs, the relative effect of top-down versus bottom-up controls on biological production, and the role of the sea ice and circulation in ecosystem dynamics. However, these studies have also highlighted the need to expand beyond regional studies over longer time periods and spatial scales because processes that occur at larger spatial and temporal scales influence what is observed at regional scales.

This recognition is the basis for the Integrating Climate and Ecosystem Dynamics (ICED) program, which is an international, multidisciplinary initiative launched in response to the increase in need to develop integrated circumpolar analyses of Southern Ocean climate and ecosystem dynamics (Murphy et al., 2008). Understanding variability at the circumpolar scale is basic to understanding ecosystem effects resulting from long-term and large-scale climate forcing and change. Large changes are taking place globally to the ocean's ecosystems (Reid et al., 2009) and the Antarctic is a key area that will determine the impact of climate change on human societies (Poore et al., 2000). The knowledge and lessons learned from the SO GLOBEC program provide a strong basis for continuing this next essential phase of interdisciplinary and internationally integrated Southern Ocean research.

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