

THE OFFICIAL MAGAZINE OF THE OCEANOGRAPHY SOCIETY

Oceanography

CITATION

Vernet, M., K.L. Smith Jr., A.O. Cefarelli, J.J. Helly, R.S. Kaufmann, H. Lin, D.G. Long, A.E. Murray, B.H. Robison, H.A. Ruhl, T.J. Shaw, A.D. Sherman, J. Sprintall, G.R. Stephenson Jr., K.M. Stuart, and B.S. Twining. 2012. Islands of ice: Influence of free-drifting Antarctic icebergs on pelagic marine ecosystems. *Oceanography* 25(3):38–39, <http://dx.doi.org/10.5670/oceanog.2012.72>.

DOI

<http://dx.doi.org/10.5670/oceanog.2012.72>

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Islands of Ice: Influence of Free-Drifting Antarctic Icebergs on Pelagic Marine Ecosystems

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Regional warming around West Antarctica, including the Antarctic Peninsula, is related to the retreat of glaciers that has resulted in significant ice mass loss in recent decades (De Angelis and Skvarca, 2003). Large icebergs (> 18.5 km long) originating from ice shelves in the Ross and Weddell Seas (Scambos et al., 2000) are attributed primarily to major loss events in these regions. Once free, icebergs become entrained in the counterclockwise Antarctic Coastal Current (Figure 1), eventually entering a strong northward flow in the Northwest Weddell Sea. We examined free-drifting icebergs in the Atlantic sector of the Southern Ocean in December 2005, aboard ARSV *Laurence M. Gould*, and in June 2008 and March/April 2009, aboard RVIB *Nathaniel B. Palmer*. Prior to these studies, little information was available about the effects of icebergs

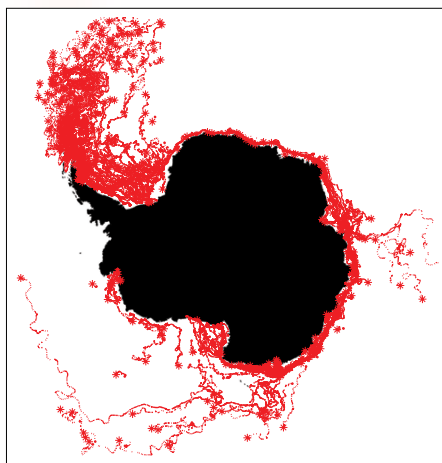


Figure 1. Tracks of icebergs around Antarctica detected by SeaWinds satellite (1999–2009) showing concentration through Iceberg Alley in the Northwest Weddell Sea (Stuart and Long, 2011).

on the pelagic realm. On these cruises, we investigated the “iceberg ecosystem” (Smith et al., 2007; Smith, 2011) to assess the degree to which icebergs are (1) hotspots of biological activity across multiple trophic levels, and (2) focal points for enhanced export of organic carbon to the deep sea. An important focus of this work was to examine the fundamental mechanisms by which icebergs affect the pelagic ecosystem, including physical disruption and effects on the availability of critical nutrients (e.g., iron, nitrate).

ECOSYSTEM STRUCTURE

We observed elevated densities of seabirds, seals, and whales in the open water regions near icebergs (Figure 2). These organisms may be feeding on Antarctic krill (*Euphausia superba*) and salps (*Salpa thompsoni*) that we collected at highest densities within ~ 2 km of an iceberg. Turbulence created by iceberg mixing and meltwater input maintains an active diatom-enriched phytoplankton community with high photosynthetic efficiency. Intense zooplankton grazing and meltwater dilution seem to explain relatively low phytoplankton densities measured close to icebergs and a “ring” of elevated phytoplankton ~ 2 km away. Other biotic effects of icebergs are apparent: diatom mats (*Thalassiosira signyensis*) attach to minerals encrusted in the ice on the iceberg flanks, providing food for krill. An iceberg-related bacterioplankton community occurs at 75–250 m depth.

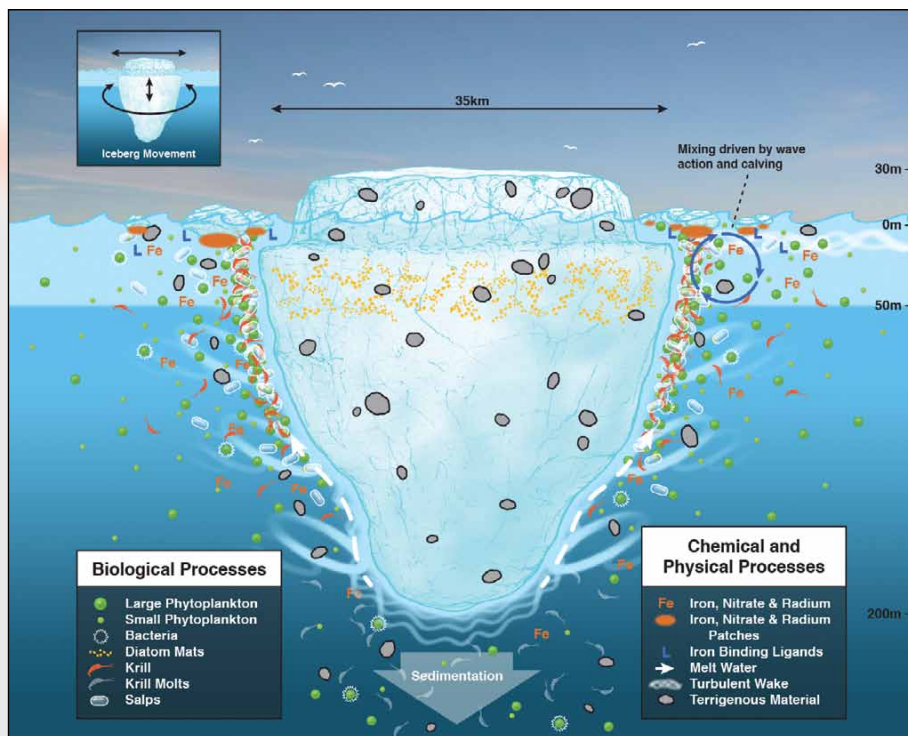
Icebergs affect their physical and chemical surroundings in significant ways. Meltwater and turbulent advection alter water column structure, as reflected in the distribution of

salinity, temperature, and carbon dioxide. At the surface, meltwater is detected as far away as 19 km and persists for at least 10 days. At depth, iceberg sidewall and basal melting contribute meltwater to the water column through diffusive and turbulent upwelling processes. Upwelling of basal meltwater mixtures appears to be localized and intermittent; however, thermohaline “staircases” consistent with sidewall melting are evident up to 19 km from iceberg C18-A in data from 2009. Horizontal spreading of meltwater provides a means by which the seasonal mixed layer can be enriched in nutrients from ice melt. Concentrations of dissolved iron in iceberg ice are elevated 5- to 600-fold above seawater, a result of accumulated terrestrial material in the ice. Highest levels of dissolved iron concentrations are associated with low-salinity waters, regardless of distance from the iceberg. Slight surface depletion of dissolved iron occurs within 1 km of icebergs, while surface enrichment is evident at most stations more than 10 km away. This observation suggests general iron enrichment in the lower-salinity surface mixed layer and enhanced iron removal, either via scavenging or biological uptake, at the iceberg face.

ECOSYSTEM FUNCTION

The iceberg ecosystem is enriched at higher trophic levels with respect to lower levels, suggesting top-down control of phytoplankton by zooplankton. Concentrations of photosynthetic pigments in the guts of *E. superba* and *S. thompsoni* track patterns in surface chlorophyll *a* and are comparable to maximum gut pigment concentrations from highly productive marginal ice zones. Iceberg systems also

Figure 2. A free-drifting iceberg acts as a floating island of ice, surrounded by meltwater, turbulent mixing, terrigenous input, and dissolved iron. Abundant krill and salps sustain localized populations of seabirds and marine mammals; all contribute to enhanced particulate carbon sedimentation to the seafloor.



show efficient trophic transfer to heterotrophic microbial production, with tight coupling of bacteria-phytoplankton production. Higher iron-binding ligand concentrations are associated with active summer plankton, indicating an important role for biologically produced ligands in enhancing the solubility and retention of dissolved iron in the waters around icebergs. Significantly, export fluxes of total mass and carbon are two to three times higher near icebergs than in surrounding iceberg-free waters. These enhanced processes, combined with the altered biological, physical, and chemical properties, create and define the iceberg ecosystem (Figure 2).

ACKNOWLEDGEMENTS

Thanks to the captains and crews of ARSV Laurence M. Gould and RVIB Nathaniel B. Palmer, to Raytheon Polar Services for technical and logistics support, and to D. Chakos and T. Gunther for figure design. This work was funded by the National Science Foundation Office of Polar Programs grants Ant-0636730, Ant-0636319, Ant-0636809, Ant-0636723, and Ant-0636543.

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