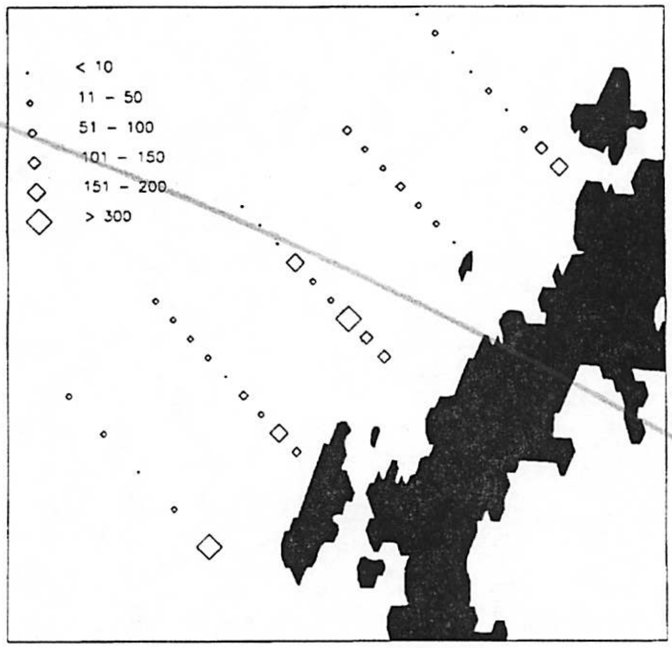


Figure 2. Mean krill biomass (g m^{-2}) detected acoustically at stations located 20 km apart along transect lines (100 km spacing) off the Antarctic Peninsula during austral summer 1993.

References

Greene, C.H., T.K. Stanton, P.H. Wiebe, and S. McClatchie. 1991. Acoustic estimates of antarctic krill. *Nature*, 349, 110.

Nero, R.W., and J.J. Magnuson. 1989. Characterization of patches along transects using high-resolution 70-kHz integrated acoustic data. *Canadian Journal of Fisheries and Aquatic Sciences*, 46(7), 2056–2064.

Quetin, L.B., R.M. Ross, and K. Baker. 1993. Palmer long-term ecological research (LTER): An overview of the 1992–1993 season. *Antarctic Journal of the U.S.*, 28(5).

Ross, R.M., and L.B. Quetin. 1992. Palmer long-term ecological research (LTER): An overview of the 1991–1992 season. *Antarctic Journal of the U.S.*, 27(5), 235–236.

Sprong, I., and P.H. Schalk. 1992. Acoustic observations on krill spring-summer migration and patchiness in the northern Weddell Sea. *Polar Biology*, 12(1), 261–268.

Waters, K.J., and R.C. Smith. 1992. Palmer LTER: A sampling grid for the Palmer LTER program. *Antarctic Journal of the U.S.*, 27(5), 236–239.

Wiebe, P.H., C.H. Greene, T.K. Stanton, and J. Burczynski. 1990. Sound scattering by live zooplankton and micronekton: Empirical studies with a dual-beam acoustical system. *Journal of the Acoustical Society of America*, 88(5), 2346–2360.

Witek, Z., J. Kalinowski, and A. Grelowski. 1988. Formation of antarctic krill concentrations in relation to hydrodynamic processes and social behavior. In D. Sahrhage (Ed.), *Antarctic ocean and resources variability*. Berlin: Springer-Verlag.

Palmer LTER: Krill distribution and biomass within coastal waters near Palmer Station

CATHY M. LASCARA, *Center for Coastal Physical Oceanography, Old Dominion University, Norfolk, Virginia 23529*
LANGDON B. QUETIN *and* ROBIN M. ROSS, *Marine Science Institute, University of California, Santa Barbara, California 93106*

The annual Palmer long-term ecological research (LTER) cruise comprised three phases in 1993 (Quetin, Ross, and Baker, *Antarctic Journal*, in this issue). Phase II (18–25 January) was an intensive multidisciplinary sampling effort designed to characterize hydrographic and bio-optical properties and the distributions of phytoplankton, antarctic krill (*Euphausia superba*), antarctic silverfish (*Pleuragramma antarcticum*), and seabirds within coastal waters south of Anvers Island. These waters encompass the summer foraging grounds for Adélie penguins (*Pygoscelis adeliae*) and south polar skuas (*Catharacta maccormicki*) found nesting near Palmer Station. The objectives of phase II were to establish biological and physical linkages within the ecosystem and to investigate the trophodynamic relationships of representative species selected by the Palmer LTER (Ross and Quetin 1992). The sampling scale was established to complement both the fine-resolution sampling conducted within the Zodiac boating limits of Palmer Station and the coarser resolution sampling conducted further offshore and along the Antarctic Peninsula.

A small-scale subgrid was defined within the LTER peninsula grid system (Waters and Smith 1992) with transect lines spaced 10 kilometers (km) apart and extending about 60 km offshore from Palmer Basin (figure 1). Sampling along this grid was implemented twice within a 1-week period in two different modes. First, to provide a nearly synoptic view of the region, the grid was traveled at a constant ship speed of 6 knots. Along-track sampling included continuous surface conductivity-temperature-depth (CTD) measurements, expendable bathythermograph (XBT) drops every 10 km, and surface chlorophyll and nutrient samples every 5 km. In addition, a 6-km acoustic tow centered within each 10-km segment of the transect grid was made, coincident with an along-track census of all seabirds. This first survey will be referred to as the fast survey because all sampling was conducted underway and the entire grid (280 linear km) was completed in 30 hours.

To allow for more detailed studies of several biological and physical processes the grid was surveyed a second time over a 3½-day period, during which the ship occupied selected stations at 20-km intervals. At each station, vertical profiles were made of hydrographic variables, bio-optical parameters, and total chlorophyll; acoustic targets were verified with net collections. During transit between stations, along-track surface hydrography and acoustical measurements were coupled with seabird censuses as described for the fast survey. A strong weather event (force 11 winds) interrupted sampling for 30 hours between the fast and slow surveys.

This article focuses on the acoustically derived krill distribution obtained from the 6-km acoustic tows using a downward-looking 120-kilohertz (kHz) dual-beam transducer. Zooplankton net samples provided verification that krill were the dominant acoustic scatterers. Echo-integration data were postprocessed as described in Lascara et al. (*Antarctic Journal*, in this issue).

During the fast survey, 26 acoustic transects totaling 148 km were made; 794 krill swarms were identified in these transects. Similarly during the slow survey, 831 swarms were found within 27 acoustic transects totaling 151 km. Based on general patch statistics (table) and frequency-distribution curves of various patch parameters (not shown), the characteristics of krill swarms were very similar between the two surveys and similar to those observed throughout the peninsula region (Lascara et al., *Antarctic Journal*, in this issue).

The vertically integrated krill biomass [in grams per square meter (g m^{-2})] was averaged for 1-km subsamples of each 6-km acoustic transect. The along-track distribution of krill biomass (figure 2) shows that, in general, krill were found throughout the entire survey region with average biomass values ranging from 0–750 g m^{-2} (mean=100 g m^{-2}). Krill biomass exceeding 200 g m^{-2} was observed in several areas during the fast (for example, near 570.035, 580.045, and 600.055) and slow (for example, near 570.030, 600.045, 600.070, and 610.075) surveys. The concentration of krill along the 590 grid line is noticeably lower than adjacent lines during both surveys. The cumulative frequency distributions (figure 3) of average biomass for all 1-km subsamples were almost identical between the two sampling periods. Therefore, over the time scale of 1 week, the krill distribution within the study area did not change despite the passage of a strong storm. Integrating a mean biomass value of 100 g m^{-2} over the foraging grounds (2,500 km^2) yields a total of 250×10^6 kg, or 0.25 million metric tons, of krill in the region.

An aggregation form resembling a cross between the superswarm and layer classification types of Kalinowski and Witek (1985) was observed for acoustic profiles of several transects during both surveys. These swarms contained dense concentrations of krill, extended horizontally for lengths of several hundred meters, appeared layerlike with vertical thicknesses ranging from 20 to 30 m, and were generally restricted to the upper 50 m of the water column. The longest swarms (1–2 km) were found during the fast survey (before the storm). Because this aggregation type was sometimes observed for consecutive 10-km segments of the grid, the biological and/or physical processes responsible for the pattern were likely operating on the scale of tens of kilometers, even though individual patches were at most 2 km in length. Similar aggregation structures have been described from acoustic observations made in the Gerlache Strait during March 1978 (Cram et al. 1979).

This research was supported by National Science Foundation grant OPP 90-11927. We thank Tim Newberger, Karen Haberman, Karen Hacecky, Caroline Shaw, Brad Seibel, and James Marquez for support in the field. (This is Palmer LTER contribution number 17.)

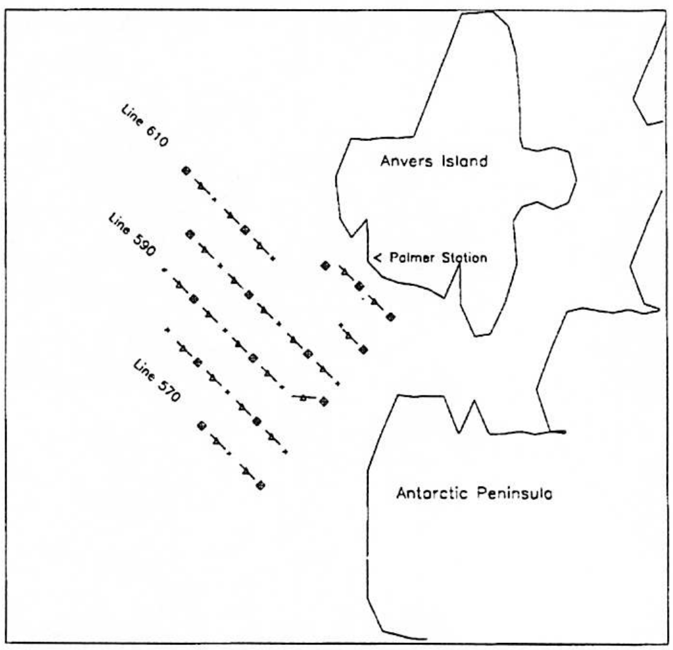
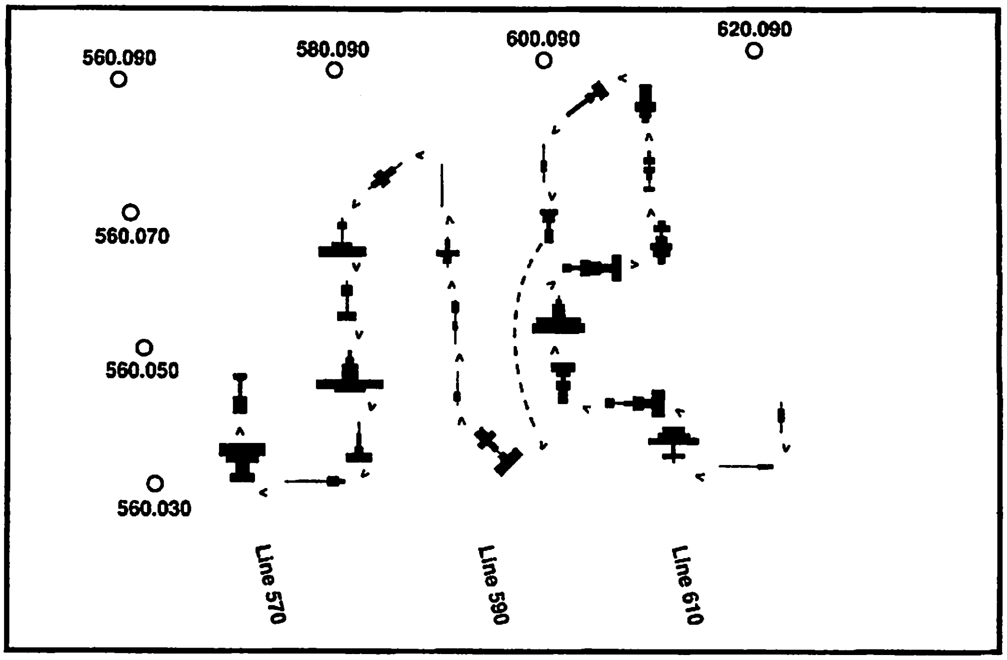


Figure 1. The sampling grid in relation to Palmer Station (on Anvers Island). The transect lines extend offshore from the Antarctic Peninsula and have along-shelf spacing of 10 km (LTER grid lines, 560–620). Sampling locations are indicated as follows: (x) XBTs and surface nutrients; (▢) BOPS and zooplankton nets on slow grid only; (△) surface nutrients; (—) 6-km acoustic tow and bird census.

Summary of statistics determined for acoustically derived krill swarms from the fast (n=794) and slow (n=831) surveys

Parameter		Minimum	Maximum	Median	Mean
Length (m)	Fast	15	2,244	26	57
	Slow	15	398	26	40
Height (m)	Fast	4	48	6	8
	Slow	4	52	6	8
Area (m^2)	Fast	60	43,036	156	547
	Slow	62	6,380	164	310
Depth (m)	Fast	8	103	37	40
	Slow	8	171	36	40
Mean biomass (g m^{-3})	Fast	0.4	325	19	39
	Slow	0.6	409	30	55
Total biomass (kg m^{-1})	Fast	0.03	973	3	16
	Slow	0.04	440	5	18

A) Alongtrack Krill Biomass (Fast Grid)



B) Alongtrack Krill Biomass (Slow Grid)

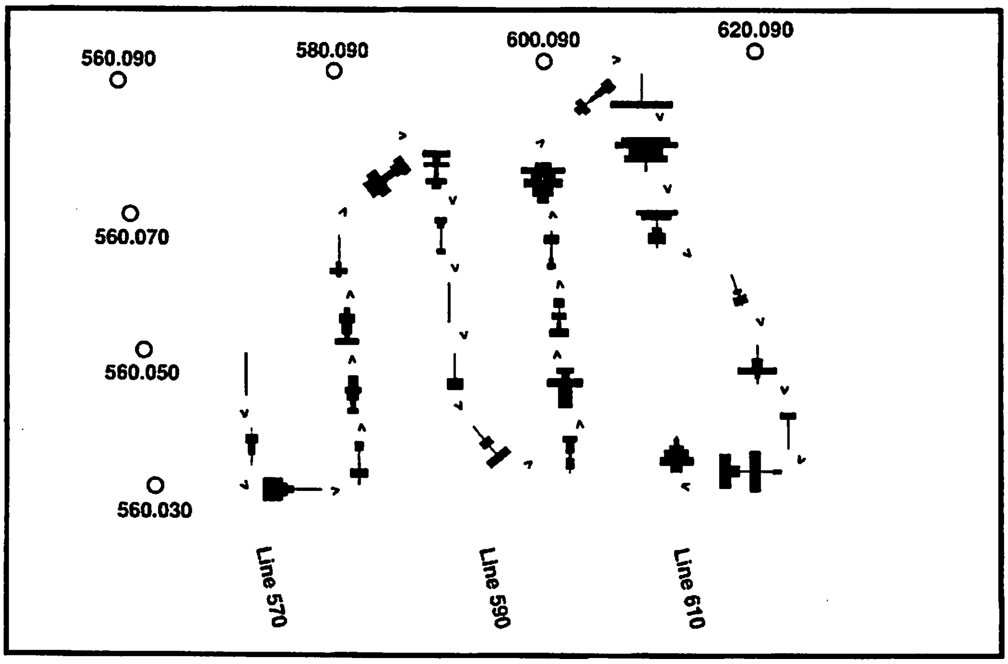


Figure 2. Along-track krill biomass (g m^{-2}) detected acoustically during the fast (*A*) and slow (*B*) survey. The width of the trackline represents the magnitude of the vertically integrated krill biomass, which was averaged for 1-km subsamples of each 6-km acoustic transect. The arrowheads indicate the direction of travel along the grid. Selected grid locations (open circle) are given as reference points. This view of the study area is rotated 45° to the right relative to figure 1.

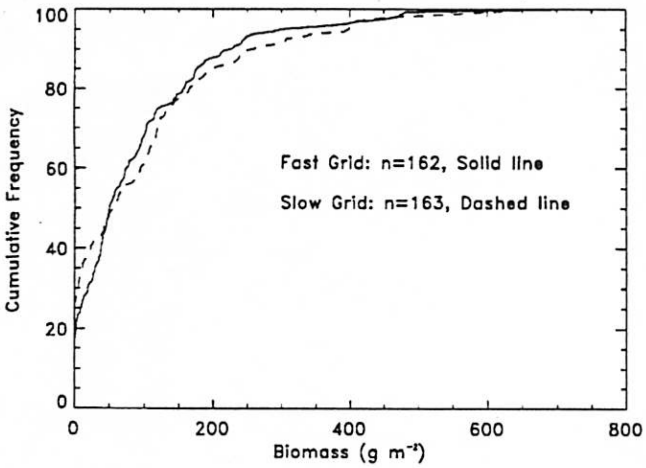


Figure 3. Cumulative frequency distribution of the mean krill biomass (g m^{-2}) of 1-km subsamples for the fast (solid line) and slow (dashed line) surveys.

References

Cram, D.L., J.J. Agenbag, I. Hampton, and A.A. Robertson. 1979. SAS *Protea* Cruise, 1978: The general results of the acoustics and remote sensing study, with recommendations for estimating the abundance of krill (*Euphausia superba* Dana). *South African Journal of Antarctic Research*, 9(1), 3–14.

Kalinowski, J., and Z. Witek. 1985. Scheme for classifying aggregations of antarctic krill (*BIOMASS Handbook* No. 27). Scientific Committee on Antarctic Research/Scientific Committee on Oceanic Research.

Lascara, C.M., E.E. Hofmann, L.B. Quetin, and R.M. Ross. 1993. Palmer LTER: Overview of krill acoustic studies and results from the Antarctic Peninsula grid. *Antarctic Journal of the U.S.*, 28(5).

Quetin, L.B., R.M. Ross, and K. Baker. 1993. PALMER long-term ecological research (LTER): An overview of the 1992–1993 season. *Antarctic Journal of the U.S.*, 28(5).

Ross, R.M., and L.B. Quetin. 1992. PALMER long-term ecological research (LTER): An overview of the 1991–1992 season. *Antarctic Journal of the U.S.*, 27(5), 235–236.

Waters, K.J., and R.C. Smith. 1992. Palmer LTER: A sampling grid for the Palmer LTER program. *Antarctic Journal of the U.S.*, 27(5), 236–239.

Palmer LTER: Grazing by the antarctic krill *Euphausia superba* on *Nitschia* sp. and *Phaeocystis* sp. monocultures

KAREN L. HABERMAN, ROBIN M. ROSS, *and* LANGDON B. QUETIN, *Marine Science Institute, University of California, Santa Barbara, California 93106*

Previous studies suggest that growth and reproduction of antarctic krill are generally food limited in the southern oceans (Ross and Quetin 1986). Although antarctic krill are primarily herbivores, it is not known whether they ingest and assimilate different types of phytoplankton with similar rates and efficiencies. Such knowledge is important if we want to understand how the patterns of phytoplankton abundance and species composition affect the krill's food availability. In particular, can food availability be accurately determined from measurements of total chlorophyll, or do we need to use more detailed measurements of species composition? The prymnesiophyte *Phaeocystis* spp. is a relevant example. Although it periodically occurs in thick blooms and can dominate the southern oceans phytoplankton assemblage at certain places and times (Prézelin et al. 1992), the question of its edibility and nutritional value for various grazers has been the subject of several investigations (Verity and Smayda 1989; Estep et al. 1990; Hansen, Tande, and Berggreen 1990; many others). Results vary widely between these studies, and none has been published on euphausiids. Here we report the results of preliminary experiments comparing the ingestion rates of krill on diatoms to those on *Phaeocystis* sp. in laboratory feeding experiments.

Between January and March 1993, ingestion rates on *Nitschia* sp. and *Phaeocystis* sp. by subadult and immature krill between 25 and 35 millimeters (mm) total length were quantified in the laboratory. Krill were collected in the Palmer nearshore area using a 500-micrometer (μm) mesh ring net deployed from a Zodiac. Experiments were conducted in large tubs containing 50 liters of a mixture of unialgal phytoplankton culture and filtered sea water. Phytoplankton were kept suspended with a plunger-type stirrer (Frost 1972). They were also mixed by hand prior to taking water samples for phytoplankton growth rates. Controls were monitored prior to a 6-hour (h) experimental period during which krill fed. Immediately prior to the experimental feeding period, krill were acclimated to the experimental food type and level by feeding for 6 h in experimental size tubs. Five 100-milliliter (mL) water samples were collected during each sampling period. Sampling intervals varied between experiments (see figures). Samples were filtered onto GF/C filters, the contents extracted in 90 percent acetone and measured on a Turner Design Model 10-005 fluorometer (Smith, Baker, and Dunstan 1981).

Experiments were conducted in parallel on *Phaeocystis* sp. and *Nitschia* sp. Initial chlorophyll-*a* concentrations were approximately equal, and krill were from the same net tow and holding aquarium. This approach allowed direct comparisons to be made between ingestion rates on different phytoplankton types while controlling for variability in experimental conditions and krill nutritional history.