Palmer Long-Term Ecological Research (LTER): Winter ecology cruise, August/September 1993 (*PD*93-7)

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The central hypothesis of the Palmer LTER program is that variability in the annual cycle of sea ice will affect the structure and functioning of the marine pelagic ecosystem in the Antarctic. This annual advance and retreat affects a large area of the southern oceans, including all of the continental shelf.

To address some specific questions on the effect of sea ice on the winter ecology of the pelagic ecosystem, the Palmer LTER conducted a pair of cruises in 1993 to compare pre- and postwinter characteristics of various aspects of the system. The cruise objectives included the following:

- documenting seasonal variability in processes of both primary and secondary production in the water column within the Palmer LTER study region by comparing abundance, distribution, and rates found in August 1993 (winter) to those found during both the previous January (summer) and March/April (fall) cruises (Quetin, Ross, and Baker 1993);
- investigating the effect of ice cover, the "age" of that ice cover, and its characteristics on abiotic and biotic characteristics of the under-ice habitat;
- documenting the effect of winter ice conditions on larval krill by comparing pre- and postwinter distribution, abundance, and physiology condition of larval krill; and
- documenting the diet and habitat of seabirds, giving special attention to Adélie penguins, in the winter.

Satellite data and observations from Palmer Station suggest that 1993 was a "light" ice year, having maximum ice coverage in September/October, not August (Stammerjohn and Smith, *Antarctic Journal*, in this issue). In mid-August the LTER grid was clear of ice, save for the southeast few hundred kilometers (200 and 300 lines; see Waters and Smith, 1992). By 24 August the entire LTER grid was covered with ice, either advected from the south or newly formed or both. The same pattern held on the smaller scale of Arthur Harbor: clear until 19 August when a thin skim of ice formed. Although north winds blew the ice out on 20 August, brash ice returned on 21 August, and cold (–7°C) and snow quickly consolidated the ice. When the *Polar Duke* arrived on 26 August, sea ice was 30–70 centimeters thick and was solid out to the surrounding islands. A satellite image on 29 August confirmed that the LTER grid was still covered with ice, and broken ice and open water extended at least 40 to 60 kilometers beyond our 600.200 position. On the same day, the R/V *Polar Duke* transected the 600 line, and we found that from 600.040 to about 600.100 the ice was a mix of glacier ice and newly formed 70- to 100-centimeter ice and that from 600.100 to 600.200 the ice was newly formed pancake ice roughly 10 centimeters thick and probably not more than a week old.

During the cruise, sea ice was encountered across the entire study region. Along the northern transect lines, sea ice was relatively new pancake ice, 30 centimeters to 1 meter thick, sometimes with visible ice algae. Ice was densely packed in the southeast corner of the grid (table 1), the location of first-year ice prior to mid-August.

At the start of the cruise, Palmer area stations B, C, D, and E were sampled before the R/V *Polar Duke* steamed for transect lines (figure) (table 1). The cruise plan included sampling the water column every 20 kilometers along the five transect lines (600, 500, 400, 300, 200) in common with the previous fall and summer cruises, using the same suite of parameters and techniques as had been used during the summer and fall. Research teams from all components were on board: optics and remote sensing, hydrography and modeling, microbial loop, primary production, secondary production, and seabird ecology. On nondiel days, time usually allowed for two full stations: BOPS (bio-optical profiling system) and water sampling for primary production, chemistry and nutrients, net sampling with simultaneous acoustic transects when ice allowed, and seabird collections for diets (table 2). When ice and weather permitted, divers conducted three 30-meter transect surveys of krill (Frazer, Quetin, and Ross in press) and other organisms; swam an under-ice transect with the profiling ultraviolet instrument; sampled the

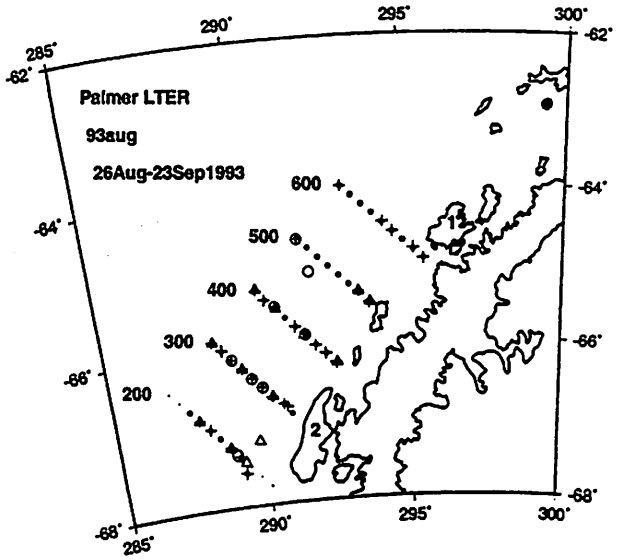
Table 1. Chronological listing of activities during the Palmer LTER winter ecology cruise, 93Aug PD93-7. [Percentage of ice cover; grid location, stations along standard transects; CTD, number of conductivity-temperature-depth casts; Dive, number, and location of under-ice SCUBA dives; PUV, location of under-ice surveys for PAR and downwelling irradiance (305, 320, 340, and 380 nanometers); Bird diet, location of stations for collection of seabirds for diet samples; empty cells mean no activity.]

Month	Day	Cruise day	Ice Coverage	Activity/ grid location	CTD	Dive	PUV	Bird diet
Aug	23			Depart Punta Arenas				
Aug	26			Arrive Palmer Station				
Aug	29	1	100	B to E				
Aug	30	2	90	600.200; 600.180		600.200		
Aug	31	3	90	600.180; 600.140				
Sep	1	4	90	600.120; 600.100		2[b] 600.120; 600.100		
Sep	2	5	60	600.100; 600.080[a]				
Sep	3	6	75	600.060; 600.040		2[b] 600.060; 2[b] 600.040		
Sep	4	7	50	600.040; 500.200		2[b] 500.200	500.200	
Sep	5	8	20–80	500.180; 500.140				
Sep	6	9	70–100	500.120; 500.100; 500.060	2			
Sep	7	10	70–100	500.080[a]		500.080		500.080
Sep	8	11	95	500.060		2[b] 500.060		500.060
Sep	9	12	100	400.040; 400.060		2[b] 400.040; 2[b] 400.060		400.040
Sep	10	13	95–100	400.080[a]		400.080		
Sep	11	14	25–90	400.100; 400.120		2[b] 400.100; 2[b] 400.120	400.100	400.100
Sep	12	15	60–80	400.120; 400.140; 400.160		2[b] 400.160	400.160	400.160
Sep	13	16	5–10	400.180; 400.200	2	400.180; 400.200		400.200
Sep	14	17	10–100	400.200; 300.200; 300.180		400.200; 300.200; 2[b] 300.180		300.200
Sep	15	18	70–100	300.180; 300.160; 300.140	3	2[b] 300.160; 300.140	300.160	300.140
Sep	16	19	90–100	300.120; 300.100; Antarctic Circle		2[b] 300.120; 2[b] 300.100	300.120; 300.100	
Sep	17	20	95–100	300.080[a]		2[b] 300.080		300.080
Sep	18	21	95–100	300.060; 300.040		2[b] 300.060; 300.040		
Sep	19	22	100	237.053 Bird/Col/Peng[c]				237.053
Sep	20	23	100	190.040	1	190.040		
Sep	21	24	100	200.060; 200.080		200.060; 200.080	200.065[b]	200.050; 200.080
Sep	22	25	100	200.100; 200.120;200.140; 200.160		200.120; 200.140		200.140
Sep	23	32				Transit		
Sep	24	33				Return to Palmer		
						Total = 4	total=7	total=12

[a]Diel station.
[b]Profiling ultraviolet instrument station on the ice surface.
[c]Seabird observations and collection; Adélie penguin diet samples.

water column, using water bottles; sampled the frazil ice for biology and chemistry, using a suction sampler; and collected krill to examine their physiological condition (figure, table 2). The PUV measured photosynthetically available radiation (PAR) and downwelling irradiance (305, 320, 340, and 380 nanometers). The ability to dive under the ice to census and sample was an important aspect of this cruise. The under-ice habitat is complex, and currently, no other way to sample the associated biota exists. En route to the next station, seabirds were censused, and expendable bathythermographs (XBTs) were launched at the 10-kilometer point between stations. Deep conductivity-temperature-depth (CTD) casts were done at specific deep stations during the overnight transit to the next station.

Four stations to investigate diel behavior in primary production were occupied at 600.080, 500.080, 400.080, and 300.080. At diel stations, a BOPS cast was made, and for a period of 12 hours, water was sampled for biology and chemistry every 3 hours. Net collections, dive collections, and seabird collections were done between BOPS casts.



Stations occupied on the winter ecology cruise, LTER 93aug *PD*93-7: BOPS ●; PUV O; dive surveys +; bird diet Δ.

Further details on data sets collected on this cruise, a roster of cruise participants, and a sampling log may be found in the online Palmer LTER information system (*http://www.icess.ucsb.edu/lter*).

Many individuals contributed to the success of this cruise. Their enthusiasm and cooperation were invaluable. We thank research team members, support personnel from Antarctic Support Associates, and specifically Captain Karl and the crew

Table 2. Data sets collected during the winter ecology cruise, Palmer LTER August 1993 PD93-7, for the mesoscale grids and frazil ice habitat. Data from frazil ice environment are not available for all stations.

Code	Data set	Meso[a]	Frazil ice[a]
BOPS	Bio-optical profiling system with rosette (conductivity, temperature, fluorescence, transmittance, irradiance, radiance, PAR)	6	6
PUV	PAR (photosynthetically available radiation) and downwelling irradiance	6	6
SHIPMET	Shipboard meteorological conditions	6	nd
CHL	Chlorophyll, phaeopigments (discrete fluorometer)	6	6
SALT	Salinity (discrete)	6	nd
ATCTD	Along-track CTD (conductivity and temperature)	6	nd
ATK	Along-track position, light	6	nd
XBT	XBT (expendable bathythermograph)	6, 8	nd
CTD	CTD with rosette, profiles to sea floor	8	nd
HPLC	HPLC (high pressure liquid chromatogaphy, 16 plant pigments)	3	3
PRODPI	Primary production vs. irradiance	3	nd
NUT	Nutrients	3	7
POC/PON	Particulate carbon and nitrogen	3	5
TRWL1M	Zooplankton (1-meter trawl)	5	nd
TRWL2M	Micronekton (2-meter trawl)	5	nd
BIOFISH	Biofish acoustic transects (120-kilohertz)	5	nd
DIVSUR	Survey by divers of under-ice habitat	5	5
PHYCONA	Physiological condition (growth, condition factor, chemical composition), adult krill	5	nd
PHYCONL	Physiological condition (as above), larval krill	5	5
ATP	Microbial biomass (adenine tri-phosphate activity)	7	nd
DON	Dissolved organic nitrogen	7	nd
DOC	Dissolved organic carbon	7	7
BAC#	Bacterial cell numbers	7	7
LPS	Total and soluble lipopolysaccharide	7	7
LEU	Microheterotrophic production (3H leucine)	7	7
EXOLUE& EXOGLU	Exoenzymatic activity of leucine aminopeptidase and B-glucosidase	7	7
H2O2	Hydrogen peroxide	7	nd
O2	Dissolved oxygen	7	nd
DIC/ALK	Dissolved inorganic carbon and alkalinity	2	2
CENSUS	Seabird census, along track		
BRDIET	Seabird diet, birds collected from Zodiac or on ice		
BIRD	Bird observations at BOPS stations	2,6	6

[a]Number in each cruise column represents the principal investigator(s) responsible for data collection: 1, Palmer LTER; 2, W. Fraser and W. Trivelpiece; 3, B. Prézelin; 5, R. Ross and L. Quetin; 6, R.C. Smith; 7, D. Karl; and 8, E. Hofmann and J. Klinck.

of the R/V *Polar Duke* who maximized time for scientific efforts. This work was supported by National Science Foundation grant OPP 90-11927 and is LTER contribution number 66.

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