Palmer Long Term Ecological Research Project

Palmer LTER: Annual January cruise for 1998 (*LMG*R98-8; *LMG*R98-1)

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Annual sampling for the sixth Palmer Long-Term Ecological Research (LTER) January cruise was completed in two legs, adding to our growing knowledge of the area west of the Antarctic Peninsula (Ross, Hofmann and Quetin et al 1996). Zooplankton sampling and bird observations within the foraging range of penguins near Palmer Station (high-density grid) was performed aboard the research ship *Abel-J* (LMGR98-8: 18 January-24 January) with 5 crew and 9 LTER science participants. The full LTER grid (transect lines 600-200) and additional inshore station sampling were performed aboard the research ship *Laurence M. Gould* (LMG98-1: 28 January-13 February) with 15 crew, 5 Antarctic Support Associates, and 21 LTER participants. The cruise began one week later than the previous January LTER cruises (Ross and Baker, 1997). The *Abel-J* was chartered for the first leg of the cruise, as research ship *Polar Duke* contract had expired and the maiden voyage of the newly built research ship *L.M.Gould* was delayed.

The tables 1 and 2 summarize the chronology (table 1) and sampling division (table 2) of the cruise. These tables summarize both the sampling over the mesoscale grid (figure 1) as well as the higher density observations within the foraging range of Adélie penguins near Palmer Station (figure 2). Initial nearshore Palmer work on the first cruise leg included repeated visits to nearshore stations (E, B, H, I, J), two transects (picket lines) that maintained a fixed distance from Palmer Stations (PL 3.7 and 10 km), and a survey of the high-density grid (HD1 10 km x 20 km) with five hydrographic stations. Stations on the LTER mesoscale grid (600.040, 600.060, and 600.080) were occupied, followed on 23 January by four inshore stations in the Lemaire and Grandidier. Measurements included optic (using a profiling radiometer) and hydrographic [hydrography using the station CTD deployed to a depth of 100 meters (m)]. Six 5-liter Go-Flo bottles were deployed routinely from the port side (using a hand winch) to collected water for nutrients, plant pigments, primary production, and plant physiology. A Palmer zodiac was used to collect krill. Bioacoustic surveys were completed aboard the *Abel-J* at 4.5 knots, the ship's minimum speed. Water for nutrient and productivity measurements was taken back to Palmer station. Nutrients were shipped to the University of California at Santa Barbara Analytic Facility for analysis.

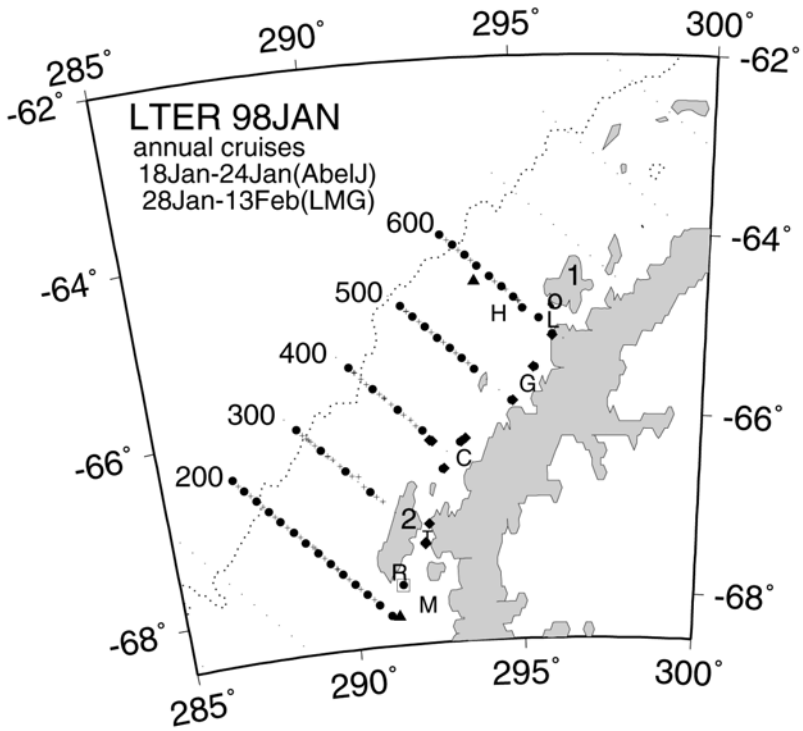

Figure 1. The cardinal station of the Palmer LTER regional grid (dots) off the Antarctic Peninsula are overlaid for LMG98-1 to indicate stations occupied (large dots), XBT stations (X) and inshore stations (diamonds), sediment trap station (triangles). Labeled are Anvers Island (1) with Palmer Station (o), Hugo AWS (H), Adelaide Island (2), Lemaire Channel (L), Gradidier (G), Crystal Sound (C), Tickle Passage (T), Marguerite Bay (B), Rothera Station (R), and Ginger Island (open square). The dotted line denotes the 1,000-meter bathymetry line.

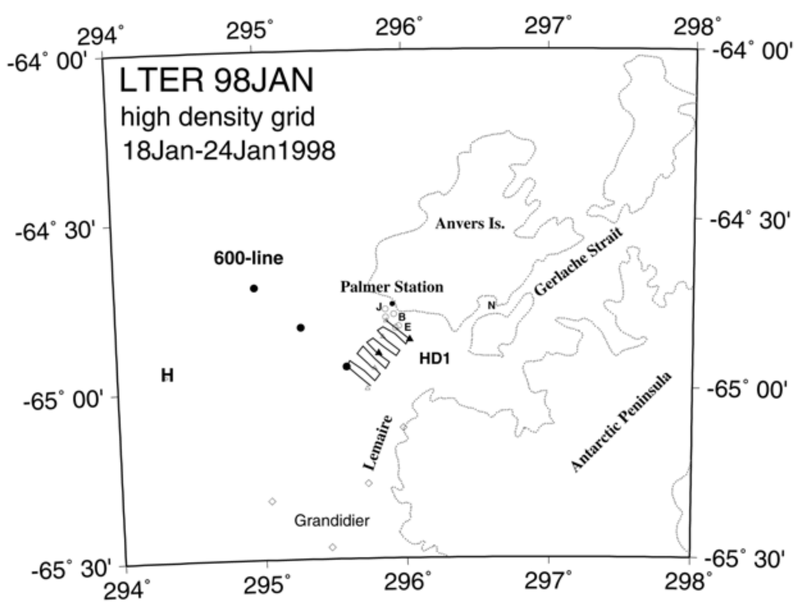

Figure 2. Sampling area near Palmer Station on Anvers Island with the Neumeyer (N) and Gerlache Strait to the East. The Hugo AWS (H) location is given. The high-density sample grid (HD1) is shown with CTD stations (triangles). Palmer stations B, E, and J are shown (open circles). The LTER regional grid 600 line stations 040,060 and 080 (filled dots and inshore stations (diamonds) are marked.

Table 1. Overview of LTER Cruises LMGR98-1 and LMG98-1. Day of the month and activities are listed including LTER grid locations (xx.xx), LTER Palmer basin stations (B, E, H, I, J), high-density grid sampling (HDI), Inland North (InN) and South (InS) stations.

January (*AbelJ)*	
13	Puerto Williams to Punta Arenas
14	Transect
15	Transect
16	Punta Arenas, Chile, arrive
17	Dock
18	E&B; dock; PL3.7; PL10
19	Dock; E; 600.040; HD1/prod (610.035; 620.030); E; dock
20	HD1 (600.030; 605.38; 610.035; 615.037; 620.040); dock
21	HD1/krilltarg; dock; zodiac
22	Zodiac; Hugo AWS; Sclause; 600.080;600.060; 600.040; dock
23	InN-LeMair (597.013); InN-Grandid (575.010; zodiac; 550.005; 550.030)
24	Dock; E; B; IJ; H; dock; Hugo
January (*L.M. Gould*)	
28	Dock; 600.040
29	B; 600.040; 600.060
30	600.080; 600.100; 600.120; 600.140
31	600.160; 600.180; 600.200
February (*L.M. Gould*)	
01	500.180; 500.160
02	500.140; 500.120; 500.100; 500.080; 500.060
03	InS-Ncrystal (430.015); 400.040; 400.060; 400.080; 400.100; 400.120; 400.060
04	400.160; 400.180; 300.180; 300.160
05	300.140; 300.120; 300.100; 300.080; 300.040
06	200.200; 200.180; 200.160
07	200.140; 200.120; 200.100
08	200.060; 200.040; 200.020; 200.000
09	20.020; 200.040; GingerIsn; 200.060
10	Trap; Tickle (295.033; 316.021)
11	InS-Crystal (380.010; 420.015); 500.00
12	InN-Grandid (550.05); Lemaire (595.015)
13	600.040; E; B; dock

On 22 January, we replaced the batteries at the Hugo Automatic Weather Station (AWS). The AWS electronics box was removed, so we could replace components, and was returned on 24 January, restoring the station to full functionality. The time spent at Hugo permitted a complete bird survey of the Hugo archipelago.

Table 2. Summary of LTER Cruises LRGR98-8 and LMG98-1 events.

Parameter	**Number of events**	**Number of days per event**	**Number of days**	**Percentage of cruise time**
Gird lines	-	-	11	46
Grid north/south	-	-	4	17
Gird inshore B, E	6	0.33	2	8
High-density grid	1	3	3	12
Picket line/3.7, 10	2	0.33	0.66	3
Bird zodiac	3	0.5	1.5	6
Weather/tests	-	-	1	4
AWS Hugo	1	-	1	4
Total			24	100

During the second cruise leg, stations on grid line transects 600 through 200 were completed with 20-km station spacing on grid lines 600, 500 and 200, and 40-km station spacing on grid lines 300 and 400, using expendable bathythermographs (XBT) to fill at 20-km spacing. To simplify equipment and personnel support, the light and hydrographic measurements were performed on separate casts (unlike the past five annual cruises). Profile measurements included hydrographic casts using the ship's CTD to a range of 500 m, with 12-liter Go-Flo bottles run from a starboard Baltic Room, as well as separate radiometer casts. Other measurements included microbial parameters, plant pigments, nutrients, primary production, plant physiology, and krill physiological measurements. Bio-acoustic transects and net tows were performed at 20-km spacing on all transect lines. Some planned acoustic work was canceled due to bubbles sweeping from the hull on the 3.5 kHz transducer port. Continuous underway measurement systems logged partial pressure of carbon dioxide, pH, dissolved oxygen, fluorescence, temperature and conductivity of near-surface waters. Adélie penguin diet samples were collected at Ginger Island (toward the end of the cruise) before proceeding to inshore stations in the South (Tickle Passage and Crystal Sound) and the North (Grandidier and Lemaire). The cruise ended with repeat visits to station 600.040 and to nearshore stations B and E.

On 30 January, the LTER sediment trap mooring near Hugo was recovered and redeployed. We were unable to deploy a trap at Marguerite Bay on 10 February.

As part of the Palmer LTER Education Outreach, Besse Dawson, a high school marine sciences teacher from Texas, was aboard ship as a participant in the NSF Teachers Experiencing Antarctica (TEA) program. She filed real-time field reports to online classrooms via the Internet. Another program supported by Palmer LTER personnel during the northbound Drake Passage crossing was the XBT study, directed by Janet Sprintall of Scripps Institution of Oceanography. Ice-free open water was observed during most of the cruise. We did encounter brash-ice in the Lemaire (inshore North) and the Tickle Passage (inshore South). We also encountered occasional high winds—on 18 January during coastal sampling; on 31 January, preventing 600.200 offshore sampling; and on 07 February during sampling of the mid 200 transect line. For the 1997-1998 season, we completed one foraging grid rather than two. Ship-based censuses in the Adélie penguin foraging area (from both *Abel-J* and the *Laurence M. Gould*) suggest that birds were concentrated inshore, within 15 km of their rookeries. This pattern is consistent with other data. We also found foraging trips to be of shorter durations, than during the 1996-1997 season; we again detected the presence of large numbers of small krill in their diets. An item that will be the subject of further discussion is the fact that compared to our former research ship *Polar Duke*, the *Lawrence M. Gould* affords much inferior visibility from its bridge for seabird and marine mammal.

Chlorophyll (chl) concentrations indicate low phytoplankton standing stocks throughout the study region, averaging less than 1-2 mg chl/m3 even in the nearshore stations. The frequently observed onshore-to-offshore gradients in chlorophyll (Smith, Baker, and Vernet et al 1998) were minimal this year as they were last year. Further, the south-to-north chlorophyll gradient is entirely absent. Surface-dissolved oxygen and dissolved carbon dioxide concentrations indicate that both biogenic gases are essentially at equilibrium with the atmosphere, unlike previous years when supersaturated dissolved oxygen and undersaturated carbon dioxide were found.

Indications are that primary production appears low, compared to previous years. Large interannual variations in the magnitude and timing of the spring-summer export have been documented. During late December 1996 and early January 1997, the 1996-1997 sediment trap samples gave dramatic visual evidence for a large export flux event (lasting for about two weeks), but no comparable export event was observed in the 1997-1998 samples (through this past austral summer prior to 8 January 1998). How the ecosystem changes we observed may relate to the 1997-1998 El Nino events will be the subject of further investigation.

This research cruise was composed of the Palmer LTER research team, including team leaders P. Duley (Fraser, S-013), C. Johnson (Smith, S-032), D. Karl (Karl, S-046), W. Kozlowski (Vernet, S-016) L.Quetin (Quetin/Ross, S-028). Special thanks to the Palmer LTER research team members, the Antarctic Support Associates, and as well as the Captain and crew of the *Abel-J* and the *Laurence Gould*. This material is based upon work supported by the National Science Foundation under OPP 96-32763, with additional funding provided by the Regents at the University of California. Palmer LTER Contribution No. 148.

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Palmer LTER: 1997 seasonal air temperature in context

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Surface air temperature records, as a measure of climate variability, are an important ecological consideration. Palmer Station weather observations provide the opportunity to consider the impact of climate on the antarctic ecosystem. In this paper, we examine air temperature data for 1997 in the context of historical data from Palmer Station, which are available as monthly data from May 1974 and as daily data from mid 1989 (Baker 1996). The data are also presented in annual summary panels along with selected Palmer Long-Term Ecosystem Research (LTER) core measurements such as water temperature, nutrients, biomass, bio-acoustics and penguin foraging and events (Baker et al, this issue).

Although long-term weather observations are subject to both equipment and observer changes, related weather data collected contemporaneously provide independent information for quality assurance. Previous work has demonstrated the correlation of daily mean air temperatures observed at Palmer Station with those from a nearby automatic weather station (Baker et al, 1995). A close relationship ahs also been found between the air temperature at Palmer and the air temperature at the near by British Antarctic Survey Faraday Station (Smith et al, 1996). Using data from 1989 to present, we found this relationship remains relatively unchanged:

$$T(palmer)=1.16 + 0.97*T(faraday)$$

with a correlation coefficient of 0.97. The linear regression shows how much warmer the temperature at Palmer is compared to the temperature at Faraday. For example, when the temperature at Faraday is 0º C, the temperature at Palmer is calculated to be 1.16º C. A harmonic fit was imposed on these data to capture the seasonal variation in the historical record (Baker, 1996).

Figure 1 shows the historical record of monthly mean temperatures in comparison to the mean harmonic fit to data from 1974 to 1998. Figure 2 shows the monthly data for the individual years 1991 through 1998, which is the period that the Palmer LTER sampling program has been in progress. Although the summer months vary within a narrow range, the winter months typically show variance as large as 7º C or more. The daily air temperature for 1997 and the monthly averages are shown in figure 3. For reference, the harmonic fit from 1974 to 1998 along with the harmonic fit from 1991 to 1998 are plotted. The nonlinear shift in the latter is noteworthy in that it displays the largest temperature increase in winter with smaller increases in spring and summer which is consistent with earlier observations (Smith et al. 1996).

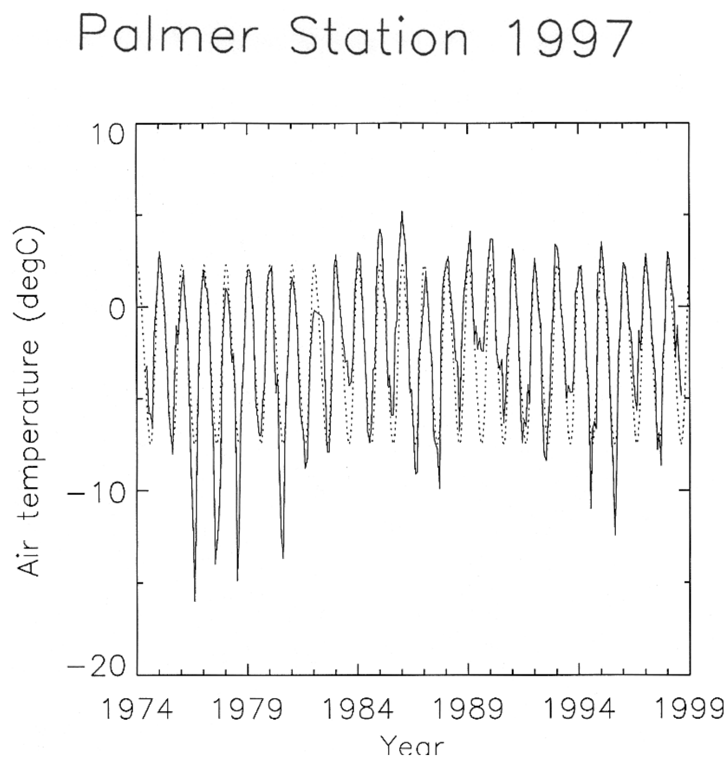

Figure 1: Monthly mean air temperature (º C) at Palmer Station versus time. The dotted curve shows the harmonic mean (1974-1997).

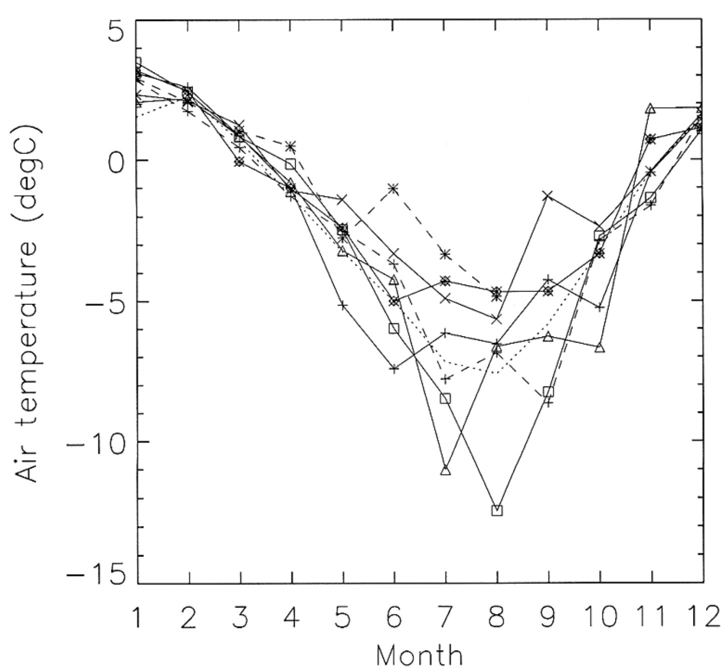

Figure 2: Monthly mean air temperatures (º C) at Palmer Station versus month for the years 1991 (plus, solid), 1992 (star, solid), 1993 (diamond, solid), 1994 (triangle, solid), 1995 (square, solid), 1996 (cross, solid), 1997 (plus, dashed), 1998 (star, dashed), and the mean air temperature over the period 1974-1998 (dotted line).

Air temperature and sea ice coverage (Stammerjohn et al., this issue) are two important indicators of major forcing functions for the antarctic ecosystem. Viewing each year's data with reference to historical averages provides a long-term context within which to interpret individual years or groups of years. Viewed within the context of the past 25 years, the Palmer LTER program, which began in 1990, has taken place during a time of relatively warmer air temperatures (figure 3).

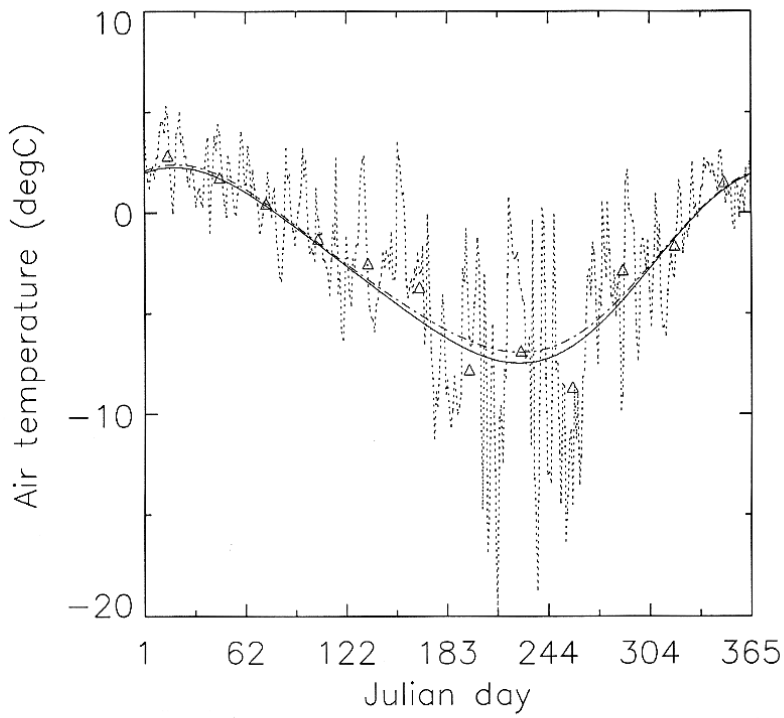

Figure 3: Palmer Station air temperature for 1997 for daily data (dotted line) as well as monthly mean (triangles) and mean air temperature harmonic fit for 1974-1998 (solid line) and for 1991-1998 (dash-dot line).

Acknowledgement and thanks are given to the special efforts of Antarctic Support Associates science technicians Al Oxton (1989-1993), Gary Wright (1994-1995), Kevin Bliss (1994-1998), Glenn Grant (1995, 1998), John Booth (1996-1997), and Jeff Otten (1998-1999) whose dedication in the field make this weather time series possible. This material is based upon work supported by the National Science Foundation grant OPP 96-32763, with additional funding provided by the Regents at the University of California. Palmer LTER Contribution No. 195.

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Palmer LTER: Annual season sampling at Palmer Station, November 1997–March 1998

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The Palmer Long-Term Ecological Research (LTER) Program (Smith et al. 1995) completed a seventh season of sampling at Palmer Station. The annual cruises, which cover a regional grid along the western Antarctic Peninsula, are part of the overall Palmer LTER sampling strategy. Our sampling strategy includes seasonal time series data from the nearshore Palmer grid and seabird observations from nesting sites near Palmer Station. The LTER January cruises (LMGR98-08 aboard *Abel-J* and LMG98-01 aboard *Lawrence M. Gould*) visited the Palmer Basin inshore stations twice to provide continuity in the seasonal record (Karl, Quetin and Baker, *Antarctic Journal*, this issue).

The table indicates the station sampling plan as modified for the 1997-98 Palmer field season. The season's sampling overview is represented in terms of the standard week defined previously (Smith et al. 1996; Baker et al, 1997). Significant dates include the arrival of research teams at Palmer (30 September and 13 November 1997), first bird observations (1 October 1997), first chlorophyll sample (19 November 1997), first zodiac profiling cast (25 November 1997), first acoustic transect (4 December 1997), start of cruise (18 January 1998), end of cruise (13 February 1998), last profiling cast (10 March 1998), acoustic transect (10 March 1998), and last LTER bird observation (4 April 1998) at Palmer Station. In the table, each line summarizes one cycle of standard sampling. The initial event number, month begun, day begun, day end, and year are given in the first five columns. The sixth column summarizes the types of standard days included in this particular cycle. Following this information are acoustic transects, hydrographic and optical profiling; phytoplankton sampling; targeted krill tows for physiological condition; instantaneous growth rate experiments; and general comments.

LTER Palmer Event Log Overview Season 1997-1998

Event No.	Mo	Day		Yr	Standard Day	bio-ac	ctd/prr/ chl/sal	hplc/ nuts/poc	net Ppi	Psis	tep	krilltarg	phycon	igr	Comments
		Beg	End												
1	11	13	17	97	—	—	—	—	—	—	—	—	—	—	ARRIVE PALMER
6	11	14	24	97	—	—	—	—	—	—	—	—	Hero	H	dive1,2
28	11	24	26	97	123	—	EB	BE	BE	BE	B	—	AH	AH	dive3
68	12	1	3	97	123	—	EB	EB	EB	EB	B	BON,F	—	F	—
105	12	4	12	97	1234	AE,JF	EBH	EB	EB	EB	B	—	—	—	—
163	12	9	14	97	123456	AE,JF	EBpierEHJ	EB	EB	EB	B	BON	Bon	Bon	—
241	12	15	21	97	123456	AE,JF	EBEHJ	EB	EB	EB	B	JAN	—	J	—
323	12	22	25	97	123	AC,AD, AE	EB	EB	EB	EB	B	C,JAN	Jan	J	—
371	12	26	29	97	456	JF	EBHJ	EB	EB	EB	B	pier	—	pier	—
412	12	30	4	97	123456	AE,JF	EBpierEH	EB	EB	EB	B	—	—	—	—
487	1	5	11	98	123456	AE,JF	EBEHJ	EB	EB	EB	B	A	—	A	—
567	1	12	17	98	123456	EA,JF	EBEHJ pier	EB	EB	EB	B	Sp	—	—	—
—	1	18	—	98	—	—	—	—	—	—	—	—	—	—	LTERJAN98 begin
—	2	23	—	98	—	—	—	—	—	—	—	—	—	—	LTERJAN98 end
659	2	18	23	98	1	AE	EB	EB	EB	EB	—	EB	—	—	—
696	2	23	28	98	123456	EA,JF	—	EB	EB	EB	B	SWI,A	A	A	—
780	31	1	6	98	1	—	—	—	—	—	—	BC,Sp	—	Sp	—
	3	2	7	98	123456	AE,JI	EBEHJB	EB	EB	EB	B	pier	pier	pier	—
870	3	10		98	123	AE	EB	EB	EB	EB	B	pier	—	—	—
—			—	98	—	—	—	—	—	—	—	—	—	—	DEPART Palmer waltercolm
—	4	16	—	98	—	—	—	—	—	—	—	—	—	—	DEPART Palmer bird

Palmer LTER: Annual January cruise for 1998 (LMGR98-8; LMG98-1)

Definitions

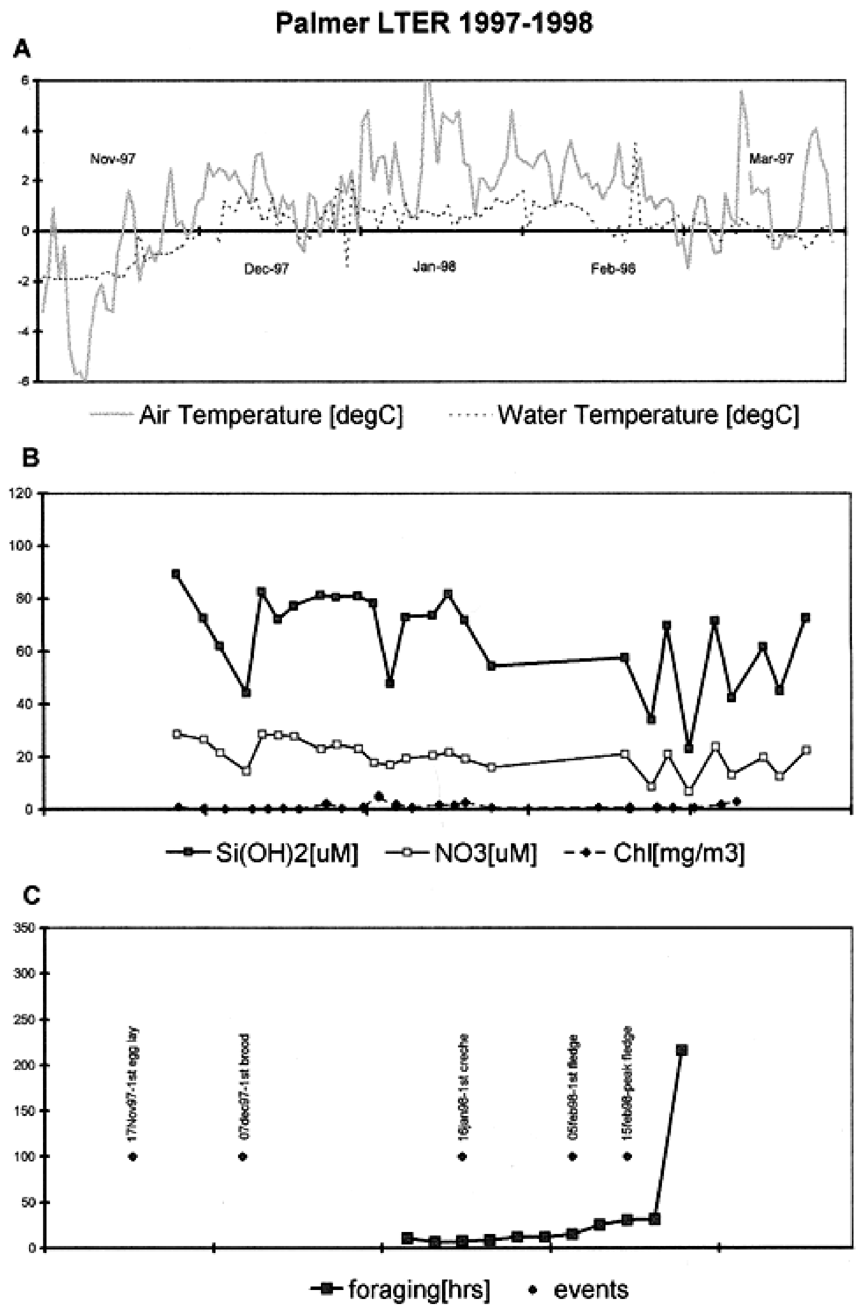
AH=Arthur Harbor	net=microscopic analysis of net plankton (>5um)
bio-ac=accoustics (Biosonics 120KHz)	nuts=inorganic Nutrient analysis
BON=Bonaparte Point	phycon=Physiological Condition of krill
chl=discrete sample for chlorophyll analysis	poc=Particulate Organic Carbon
ctd=Conductivity Temperature Depth (Seabird)	Ppi=Production photosynthesis vs irradiance
Hero=Hero Inlet	Psis=Primary Production simulated-in-situ
hplc=High Performance Liquid Chromotography of phytoplankton pigments	prr=Profiling Radiometer (BSI)
igr=Instantaneous Growth	sal=discrete sample for salinity analysis
JAN=	SWI=station seawater intake
krilltarg=targeted tow for krill	tep=transparent exopolymer particles

The sampling program changed somewhat from previous seasons. With six LTER personnel representing four of the LTER's projects for the 1997-1998 season, the daily sampling week included sampling 4 stations instead of 9 for profiling weekly hydro-bio-optics, 2 stations twice weekly instead of 4 for phytoplankton sampling, growth experiments every 2 weeks instead of weekly, sampling for condition factor of young of the year only, and eliminating standard zooplankton tows. Further, nutrient samples were shipped to the University of California Santa Barbara Analytic Facility for analysis. At Palmer new digital detectors replaced old analog sensors for nutrient hardware, and Alpkem EnviroFLow version 2.1 software was purchased.

The hardware and software for HPLC analysis remained the same as last year. This season the satellite network link with LES9 provided two blocks of about 5 hours of time online per day, making possible FTP file transfer of data and real-time electronic talk communication via electronic chat programs. The ability to transfer data daily allowed us to conduct real-time data analysis at the home institutions and to archive the data timely and efficient. Besides standard chlorophyll samples run in replicate for the greater-than-0.45-micrometer phytoplankton at selected depths, the less-than-20-micrometer fraction was sampled at the 50percent light level (ranging from 3.0 m to 12 m). We also ran hydrographic profiles station Janus (D. Karentz personal communication) and at the pier (A. Amos personal communication). Concurrent deployments last year with the station's STD instrument will permit comparison studies.

During the 1997-1998 austral season, ice conditions changed in September when the fast ice blew out of Arthur Harbor and was replaced a few days later by pack ice, which persisted until the ice broke up in November. The ship, arriving on 13 November 1997, broke up the ice in Arthur Harbor. Ice had cleared from the Palmer basin by 25 November, when the first zodiac work began. Unconstrained by the presence of brash ice, zodiac operations were simplified this season. This spring-summer was preceded by an above average winter of ice similar to that of 1995-1996 when pack ice did not begin to clear from the nearshore Palmer region until November 1995.

Preliminary data show seasonal progression in selected parameters through the spring and summer (figure), providing an overview of the season. During the 1997-1998, low chlorophyll biomass was recorded in November through December, with surface phytoplankton blooms of 2-5 milligrams per cubic meter in January at stations B and E. Between November 22 and March 21, we ran 11 acoustic transects from stations A to E (figure C) and 9 from F to J. We collected krill collected from target tows were measured for length-frequency distributions throughout the season. This season, we saw only a few salps, which were observed at the surface after a cruise from the zodiac. Reproductive events associated with breeding chronology of Adélie penguins on Humble Island (Fraser et al. in press) are noted by arrows in Figure 1c. The Adélie penguin breeding population size, a measure of winter survival, decreased by 3.6 percent relative to the past season, while the per-pair breeding success of these penguins was 1.58 chicks creched per pair, representing an increase of 7.0 percent relative to the 1996-1997 season. The increase in breeding success of 0.11 chicks per pair may be partly attributable to a lack of tick infestations early in the season. The breeding chronology and mean fledging weights were unchanged from last year.



A. ***Air temperature (° C; heavy line) and water temperature (° C; dashed line) at Palmer Station for the 1997-1998 season.*** **B.** ***Surface chlorophyll (in mg/m^3; filled diamonds), nitrate (micromolar; open squares), and silicate (micromolar; filled squares) at Station E for the 1997-1998 season.*** **C.** ***Adélie penguin foraging; filled squares denote hours. Arrows indicate day of first egg laying, first brood, first creche, first fledging, and peak fledging at Humble Island for the 1997-1998 season.***

The LTER seasonal observations of the marine environment, the lower-trophic level abundance and distributions for the area, and the seabird observations at nesting sites near Palmer were recorded from November 1997 to March 1998. The sampling event log, participant list, and other project information for the season are available online (http://www.icess.ucsb.edu/lter).

Acknowledgement and thanks are given to members of the Palmer LTER research team and to Antarctic Support Associates. This material is based upon work supported by the National Science Foundation grant OPP 96-32763, with additional funding provided by the Regents at the University of California. Palmer LTER Contribution No. 196.

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Palmer LTER: 1997 seasonal sea-ice variability in context

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To understand the ecological impact of sea ice is to appreciate the complex matrix of physics and biology. A recent study (Smith et al. 1998) explores this complex matrix and proposes a set of sea ice indexes for quantifying the variability of sea ice on scales relevant to ice-ecosystem interactions. The approach recognizes the need for multiple spatial and temporal scales and for consistency in how these scales are defined and interpreted. A variety of temporal scales is needed to capture both the seasonal and interannual variability of the physics and the biology. Additionally, a variety of spatial scales is needed to capture the regional extent of physical influence and the distribution and migration patterns of species within the ecosystem. Once sea ice indexes are identified, they provide not only a quantitative and consistent definition of the timing and magnitude of sea ice but also a common context to better resolve ice-ecosystem dynamics. This work will highlight a few of the spatial and temporal scales explored in Smith et al. (1998) by examining 1997 sea-ice variability in the context of previous daily (1991-1997) and monthly (1979-1998) seasonal sea ice coverage.

Passive microwave satellite data provide the only continuous time-series of sea ice coverage in the polar regions. Sea-ice concentrations derived from these data are available from the National Snow and Ice Data Center's Distributed Active Archive Center at the University of Colorado (http://www-nsidc.colorado.edu/). We have used these data to describe the spatial and temporal variability and to identify trends of regional Southern Ocean sea ice (Smith et al. 1998; Stammerjohn and Smith 1996,1997). Here we summarize the seasonal variability of sea ice in the Palmer LTER study region, emphasizing the period when Palmer LTER field studies began (1991) to the most recently available satellite data (March 1998).

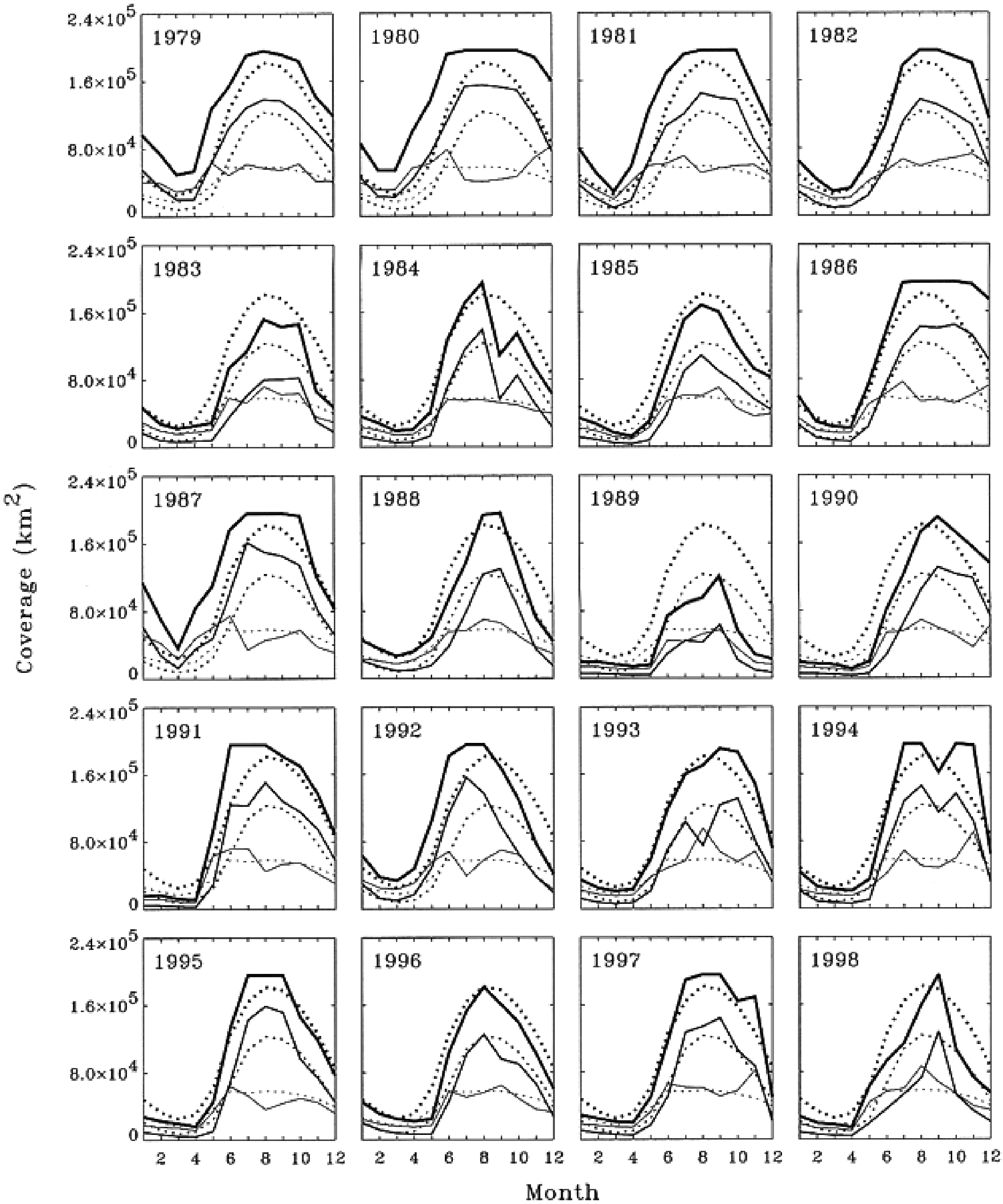

Figure 1. Annual curves of monthly sea ice extent (thick line), sea ice area (medium line) and open water area (thin line) for the Palmer LTER region. Dotted lines represent the means (11/78-3/98) for each sea ice variable.

Figure 1 shows the monthly averages of sea ice extent, sea ice area, and open water area from January 1979 to March 1998 for the Palmer LTER study area. The dotted lines denote the long-term means and accentuate the variability in the annual progression of sea ice. For example, years 1991 and 1992 had above-mean autumn sea-ice coverage, indicating rapid and early sea ice growth that, in turn, lead to an early winter maximum. Year 1992, in contrast to 1991, had below-mean spring sea-ice coverage, indicating an extremely early spring sea-ice retreat. Other years with above-mean spring sea-ice coverage (1993, 1994 and 1997) indicate a late spring sea ice retreat. Season averages for all of the Palmer LTER years (1991-97) reveal averaged that all years except 1993 and 1996 had above-mean winter sea ice extent and that all years except 1992 had below-mean summer sea-ice extent.

Smith et al. (1998) observed that the monthly anomalies persisted from the late 1970s to the late 1980s, so that several years of positive monthly anomalies followed several years of negative monthly anomalies, an oscillation that repeated twice. However, the anomalies in the 1990s show less persistence, and variability between seasons is higher. This is illustrated in figure 2, where daily data for year 1997 and for the Palmer LTER mean (January 1991 to December 1997) are contrasted to monthly data for the historical mean (November 1978 to March 1998). The nonlinear shift in the Palmer LTER mean with respect to the historical mean (whereby different months show different shifts from the longer-term mean) is due to the greater variability within the seasonal cycle in the 1990s versus the 1980s.

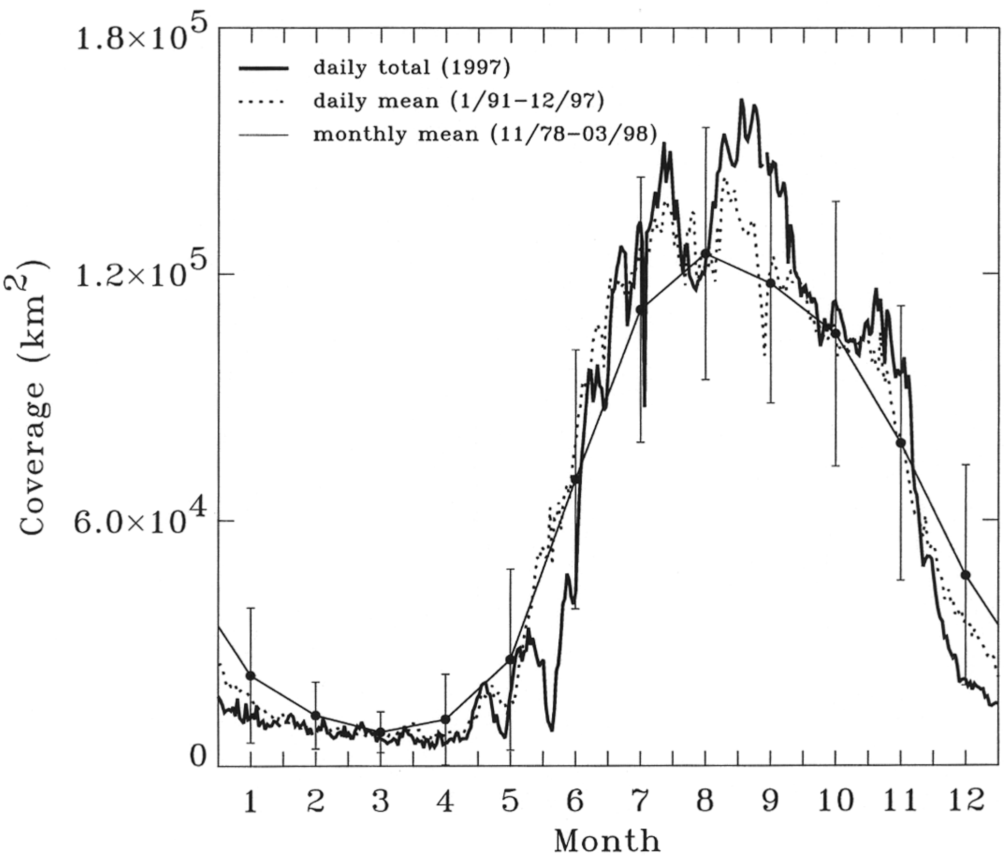

Figure 2. Palmer LTER 1997 daily sea ice area (thick line), with daily mean (1/91-12/97, dotted line) and monthly mean (11/78-3/98, thin line) with standard deviation.

Year 1997 exemplifies the 1990s trend in two ways. First, sea-ice coverage in summer, early autumn, and late spring is below not only the long-term mean but often also the Palmer LTER mean. Second, sea-ice coverage from late autumn to early spring is not only above the long-term mean but often also the Palmer LTER mean. Figure 2 also illustrates the quasi-weekly oscillations in the daily time-series. A recent preliminary study of the high-frequency variability of sea ice in the western Antarctic Peninsula region shows that the movement of sea ice and the consequent changes in surface concentrations are largely due to wind forcing from passing weather systems (Stammerjohn et al. 1998).

The Palmer LTER study region spans 6 degrees of latitude, from a southern region of fairly consistent winter sea-ice coverage to a northern region of extremely high variability. As an example of the various spatial scales of sea-ice variability, figure 3 shows 1997 monthly sea-ice coverage for several regions surrounding the Antarctic Peninsula. In general, the Bellingshausen and Palmer LTER regions have extremely low sea ice in the summer and high sea ice in the winter. Both of these regions encompass broad latitudinal bands of seasonal sea-ice coverage. The southwest Peninsula annual curves of sea ice extent and area are distinguished by broad winter maximums, which are typical of colder, more southern regions (though the extremely low summer sea ice is also notable). The Weddell Sea annual curves of sea ice extent and area are most notable for the extremely high spring sea ice and, consequently, late spring sea ice retreat. The northern Peninsula shows a mix of highly seasonal sea ice (from the northwest) and perennial sea ice (from the east). The late autumn advance is probably due to the late advance in the western Antarctic Peninsula region, while the late spring retreat is more due to the late spring retreat in the eastern Antarctic Peninsula region (also reflected in the greater Weddell region). The differences and similarities among the regions in figure 3 stress the importance of defining the relevant spatial scales of physical forcing and biological response.

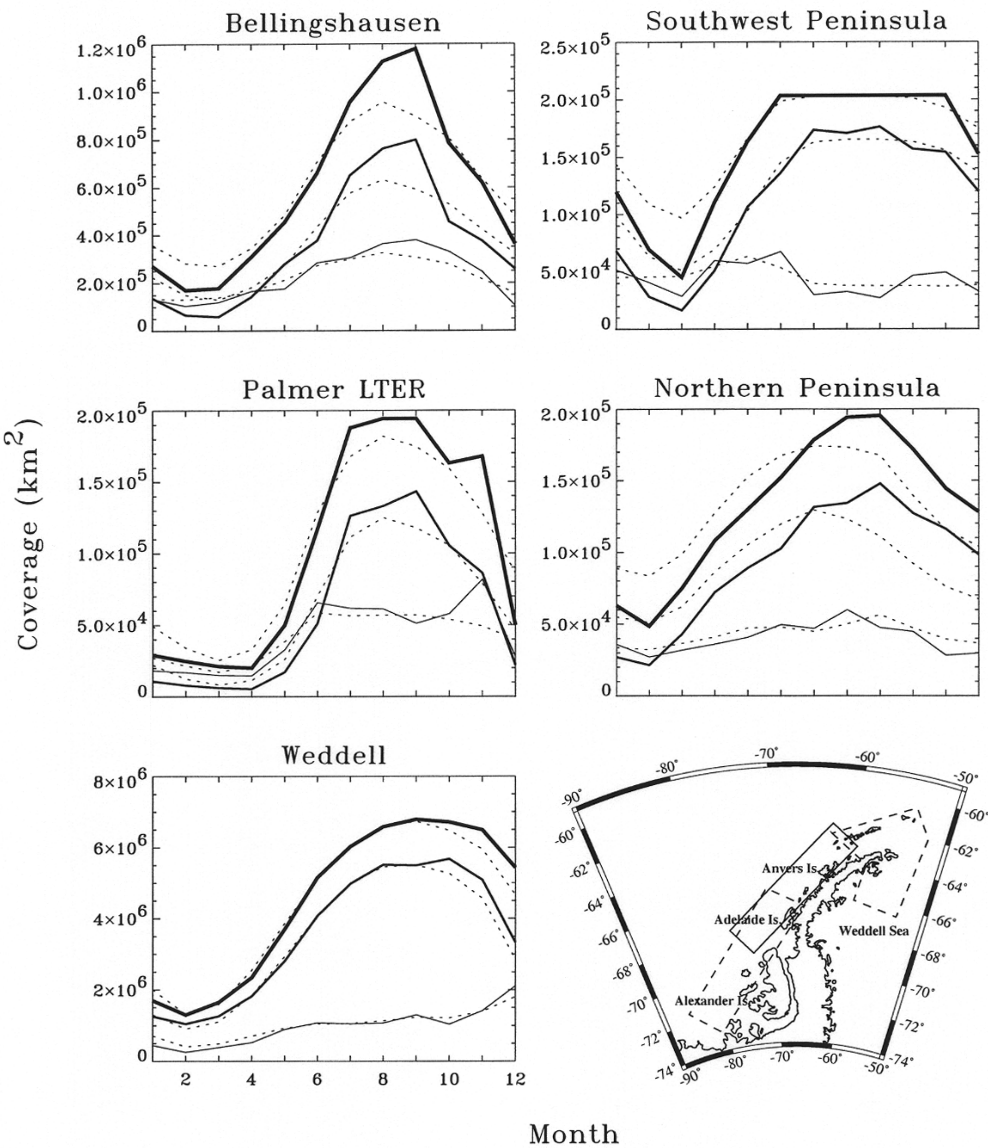

Figure 3. Annual curves of 1997 sea ice coverage for several regions surrounding the Antarctic Peninsula. The last panel shows a map of the southwest Peninsula, Palmer LTER and northern Peninsula regions. The Bellingshausen and Weddell regions include pie sections from 60-90 degrees West and 20 degrees East - 60 degrees West, respectively. Lines are as in Figure 1.

In summary, we have emphasized here the timing of the seasonal progression of sea ice during the Palmer LTER years (1991-1997). With the exception of 1996, all of these years had annual means that were within a half standard deviation of the historical mean. In short, the annual magnitude does not describe the high seasonal variability observed during the Palmer LTER years. As noted in Smith et al. (1995, 1998), the timing of seasonal physical forcing is crucial to many biological processes in the antarctic marine ecosystem, and high seasonal variability does impact ice-ecosystem dynamics. As the 1990s (thus far) exhibit less persistence in anomalous sea-ice coverage than the previous decade did, it is vital to develop consistently defined, multiple, spatial and temporal scales of sea-ice variability.

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Palmer LTER: Annual January Cruise for 1999 (LMG99-1)

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Each austral summer since 1993, the Palmer Long-Term Ecological Research (LTER) program has surveyed the continental shelf and slope west of the Antarctic Peninsula and between Anvers and Adelaide islands. The mesoscale study region is covered by a standard grid set up at the initiation of the LTER program (Waters and Smith 1992).

During the 1999 cruise aboard the research ship *Laurence M. Gould* (LMG99-1) sampling occurred between 8 January and 12 February. The cruise plan (tables 1 and 2) included standard cardinal transect lines (figure 1), high density sampling within the foraging range of Adélie penguins nesting near Palmer Station (figure 2), periodic visits to the seasonal stations within 3.7 km of Palmer Station, and spatial variance transects. Three of the five major cruise objectives are common to all January cruises:

1. to document spatial and interannual variation in core physical and biological variables along and offshore;
2. to investigate the linkage between marine resources and Adélie penguins during a time of peak food requirements for the chicks; and
3. to maintain seasonal sampling on the Palmer nearshore stations.

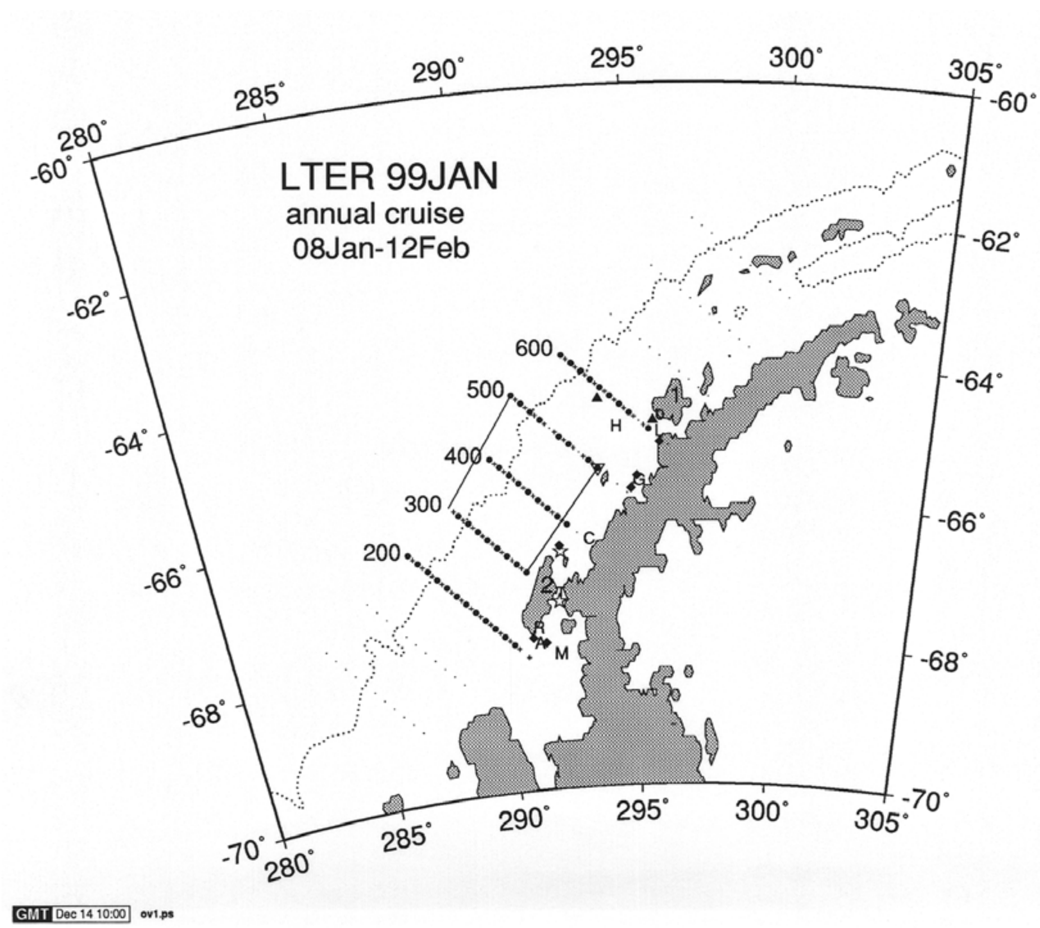

Figure 1. The cardinal stations of the Palmer LTER regional grid (dots) off the Antarctic Peninsula are overlaid to indicate standard station sampling with CTD (large dots) and with XBT (cross) during LMG99-1. Lines show spatial variance transects for inside and outside grid stations. Inside stations are labeled with filled diamonds. Labeled are Palmer Station (o), Anvers Island (1), Adelaide Island (2), Marguerite Bay (M), Avian Island (A), Rothera Station ®, Tickle Channel (T), Crystal Sound (C), Grandidier (G), Lemaire Channel (L), Hugo Automatic Weather Station (H; 64deg 57'S, 65deg 41'W), sediment traps (filled triangles), drifter deployment (unfilled triangle), and sea ice experiments (star). The 1000 m bathymetry line (dotted) is shown.

The Palmer nearshore stations are sampled from zodiacs from November through March to document interannual variability in seasonal patterns. The fourth objective for 99Jan LTER was to continue a study of spatial variance initiated in 97Jan LTER. Data on a subset of the core parameters were collected continuously both between stations on the 5 standard cardinal transect lines (~ 200 km each), and alongshore both on the outer slope and the inner shelf (~ 200 km each). The fifth objective was to repeat a subset of the initial regime on two of the cardinal transects, one at the north end of the LTER sampling region (600.*) and one at the south end (300.*) to determine if timing of the various processes is the same all over the grid or moves north to south in a temporal sequence.

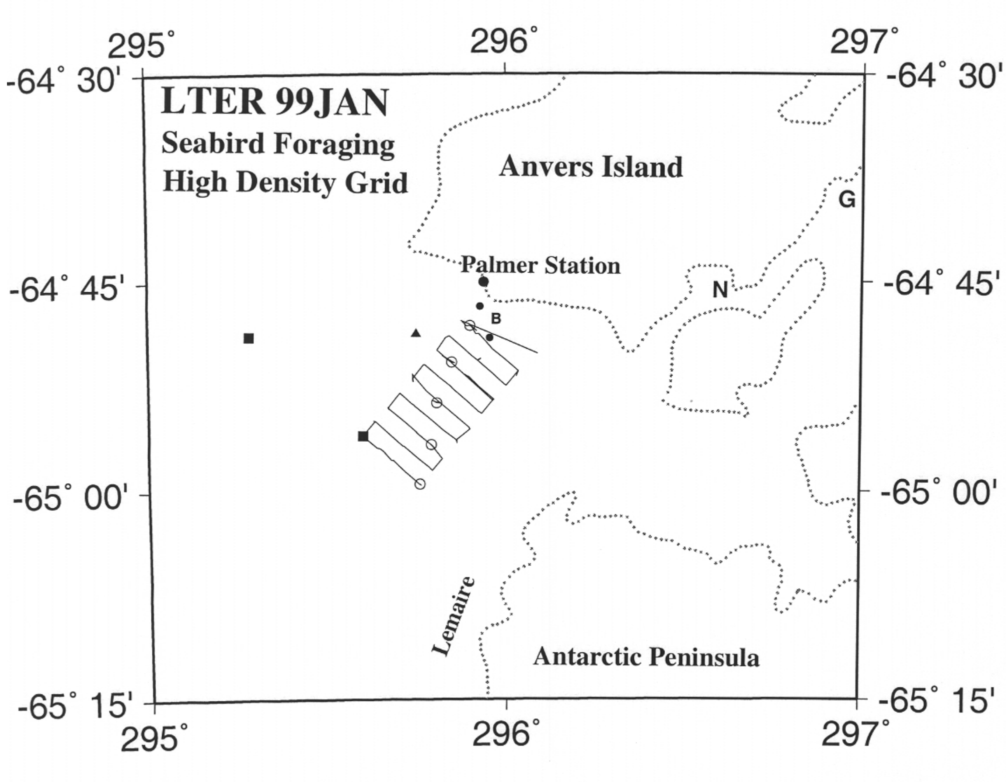

Figure 2. Sampling area near Palmer Station on Anvers Island with the Neumeyer (N) and Gerlache Strait (G) to the East and the Lemaire to the South. The LTER regional grid 600 line stations 040 and 060 (filled squares) and two sediment traps (triangle) are marked. The high-density grid (lines) with CTD stations (open circles) and the location of inshore stations (filled circles) of the Palmer grid are shown.

Table 1. Overview of the LTER cruise LMG99-01 where the day of the month and activities are listed including LTER grid locations (xxx.xxx). LTER Palmer basin stations (A, B, E, F, J), high-density grid sampling (HD1), Inside Islands North (InN) and South (InS) stations.

Date	Site
January	
02	Punta Arenas depart
03	Transect
04	Transect
05	Palmer arrive
06	Palmer dock
07	Palmer dock
08	Tests, B&E
09	InN: Grandidier (510.000,530.005)
10	500.060, Drifter deploy
11	500.120, 500.140, 500.16012
12	500.200, 500.220
13	500.240, Transect Outside 500.240 to 300.200
14	300.180
15	300.160, 300.140
16	300.140, 300.120, 300.100
17	300.080. 300.060, 300.040
18	600.040, 600.060
19	600.080, 600.100, 600.120
20	600.140, 600.160, TrapHugo retrieve, 600.180
21	600.220, 600.200, 600.180
22	HD1 (620.040), Transect 600, dock A-E, F-J
23	InN: Lemaire (595.014), B, E, TrapPalmer deploy
24	HD1 (610.040, 620.040, 615.037, 610.035, 605.032)
25	600.030, TrapHugo deploy
26	400.200, 400.180, 400.160, 400.140
27	400.160, 400.140, 400.120
28	400.080, 400.040
29	200.040, 200.020, 200.000

Date	Site
30	200.-020, Rothera dock
31	AvianIs (235.-56), diet & GPS, CTD (with BAS)
February	
01	Avian Island, 200.-06, SeaIce Tickle
02	200.060 200.080, 200.100
03	200.120, 200.140, 200.160
04	200.180, 200.200
05	300.200, 300.180, 300.160, 300.140, 300.120, 300.100
06	300.080, 300.060, 300.040, SeaIce Crystal_Sound/Matha_Strait, 366.028
07	400.00, Crossing Ceremony, Transect Inside 300.040 to 500.060
08	Transect 500
09	600.100deep, 500.160deep, 600.200, 600.180
10	600.160, 600.140, 600.120, 600.100, 600.080
11	B, E, 600.060, 600.040
12	Palmer dock
13	Palmer dock
14	Palmer depart
15	Transect
16	Transect
17	Transect
18	Punta Arenas arrive

Table 2. Summary of LTER Cruise LMG99-1 events.

Parameter	Number of events	Number of days per event	Number of days	Percentage of cruise
Grid lines	x	x	23	66%
Grid north/south	2	1	2	6%
Grid inshore B, E	3	0.33	1	3%
High-density grid	1	2	2	6%
Picket line/3.7, 10	0	0.33	0	–
Bird zodiac	0	–	0	–
Weather/tests	2	–	1	3%
AWS Hugo	–	–	0	–
Spatial Variance Transect	2	1	2	6%
Traps	3	0.33	1.0	3%
Drifter	1	0.33	0.3	1%
Rothera/Avian Island	2.5	2.5	2.5	7%
Total			35	100%

In addition, we retrieved and re-deployed the Hugo sediment trap, and deployed a new trap outside the Outcast Islands south of Anvers Island. The moored sediment trap array near Hugo Island now includes an ice sonar that senses both the presence and thickness of sea ice. This is the eighth deployment at the Hugo site. Cooperative studies with scientists at Rothera Station continued, with 16 British Antarctic Survey scientists joining the *Laurence M. Gould* on January 31. We accomplished three major objectives that day:

- sampling the diet of Adélie penguins nesting on Avian Island (19 samples);
- landing of a BAS team on Avian Island to complete global positioning system work;
- establishing a full water-column station, during which we compared data from the LTER and BAS CTDs to 200 m and did a deep water bottle cast for biogenic N and S gases.

We anticipate that the comparison of the seasonal dynamics in the two areas separated by 400 km will be enlightening.

Standard measurements at stations 20 kilometers apart on cardinal transect lines included: a PRR/PUV cast to measure downwelling and upwelling radiation in UV and visible wavelengths; a shallow CTD cast with a HydroScat to measure backscattering in 6 visible wavelengths; a core CTD cast with full bottle sampling to characterize the gases, nutrients and living microorganisms, including primary producers, in the water column; 2

net tows with simultaneous bioacoustic transects; and seabird observations. Experiments were conducted at selected stations with the microorganisms and Antarctic krill collected. Both measurements of backscattering and of the spectral absorption by total particulate, detrital and chromophoric dissolved organic matter were parameters added by graduate student research projects. Underway measurements between stations included: seabird distributions; bioacoustics (120 kHz); continuous surface temperature, salinity, fluorescence, carbon dioxide partial pressure (as measured with a carbon dioxide equilibrator system), dissolved oxygen, pH and nitrate; and discrete samples taken at hourly intervals for nutrients and chlorophyll a.

Sea ice was only encountered in the southern part of Grandidier Channel (inside North), the inner reaches of Crystal Sound (inside South), and Tickle Channel in Marguerite Bay. The skies were consistently overcast, and light levels low even at mid-day. Chlorophyll a and primary productivity values were low, close to baseline, with the exception of the stations in the Grandidier Channel and near Avian Island at the mouth of Marguerite Bay. However, surface waters were undersaturated in CO_2. For higher trophic levels, salps and krill co-occurred at many stations, with Antarctic krill abundances at average levels.

In addition, intensive sampling was conducted within the foraging area of Adélie penguins whose reproductive success and foraging ecology was being studied simultaneously by investigators at Palmer Station. The relative distributions of the predator (Adélie penguins) and prey (Antarctic krill) were observed on a high density grid at 2.5 km spacing, as described for 95 January (Quetin et al. 1995) (figure 2). On 19 January one of four giant petrels nesting near Palmer Station and fitted with a satellite transmitter was spotted from the bridge. This sighting will provide an accurate test of the Argos positions for this project.

This research cruise was a result of a productive team composed of Palmer LTER research teams, Antarctic Support Associates personnel with MPC R. Sleister, and Captain Warren Sanamo and his crew of the RESEARCH SHIP LM Gould. Our grateful appreciation is extended to all. This research was supported by National Science Foundation grant OPP 96-9632763 with additional funding provided by the Regents at the University of California.

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Palmer LTER: Annual season sampling at Palmer Station, October 1998-April 1999

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The Palmer Long-Term Ecological Research (LTER) Program (Smith et al., 1995) completed an eighth season of sampling at Palmer Station. The Palmer LTER sampling strategy combines seasonal time series data from the nearshore Palmer grid and seabird observations from nesting sites near Palmer Station, with annual cruises that cover a regional grid along the western Antarctic Peninsula. The LTER January cruise, LMG99-01 aboard the research ship *Laurence M. Gould*, visited the Palmer Basin inshore stations three times (8 January, 23 January, and 11 February) to provide continuity in the inshore seasonal record (Ross and Baker this issue).

The original station sampling plan (Smith et al 1996) was modified for the 1998-1999 Palmer field season to include a 3-4 day cycle of water column sampling largely at stations B & E and weekly or biweekly sampling for bioacoustics (table 1). Table 2 summarizes this season's sampling specifics.

Significant dates include arrival of first research teams at Palmer (01 October), first chlorophyll sample (16 October 1998), first zodiac profiling cast (21 October 1998), arrival of subsequent research teams at Palmer (10 November), first bird observations (10 December 1998), start of cruise (08 January 1999), end of cruise (12 February 1999), first station Bionomics acoustic transect (16 February 1999), last profiling cast (02 March 1999), last acoustic transect (06 March 1999), and last LTER bird observation in early April at Palmer Station.

Table 1. LTER Palmer 9899 planned sampling cycle: Water-column and Adélie penguin

Planned sampling events include acoustics (bio-ac, Furuno 50KHz and Biosonics 120 KHz), discrete sample for chlorophyll analysis (chl), total particulate absorption (Ap), detrital particulate absorption (Ad), dissolved organic matter absorption (Acdom), conductivity-temperature-depth (ctd, Seabird), high-performance liquid chromotography of phytoplankton pigments (hpic), instantaneous growth rate (igr), targeted tow for krill (krilltarg, Furuno 50 KHz), microscopic analysis of net plankton (net, >5um), inorganic nutirent analysis (nuts), photosynthetically active radiation (par), physiological condition (phycon), microscopic analysis of picoplankton (pico, 0-5-5. Ourn), particulate organic carbon and nitrogen (chn: poc, pon), production photosynthesis versus irradiance (Ppi), primary production simulated-in-situ (Psis), profiling visible radiometer/profiling ultraviolet radiometer (prr/puv, BSI) package, and transparent exopolymer particles (tep). Station locations include aquatic inshore A through E within 3.2-kilometer (2-mile) limit of Palmer and islands Humble (Hu), Torgersen (To), Christine (Ch), Cormorant (Co), and Litchfield (Li).

Date	Frequency	Location	Activity
01 Oct-08 Jan			
14 Feb-13 Mar			
	Twice/week	Palmer Basin	Zodiac: water-column sampling
	Day1	E & B	ROZEJr: profile CTD, prr/puv
	Day 1	E & B	LEGEND: profile par, hplc, nuts, chn, Ppi (3, temp), Psis, tep, net, pico, rignet, Ap, Acdom
	Day 1	BON,GAM	LEGEND: chlsurf
	Day 1	–	LAB: filter samples, scan Acdom start 24h SIS experiments
	Day 2	–	LAB: scan Ap, start Ad extract, read chl conclude 24-hr prod experiments, conclude PI experiments, extract hplc
	Day 3	–	LAB: scan Ad, process CTD/PRR
	Twice/week	Area	SCUBA dive (when ice cover)
	Weekly	A to E & F to J	ROZE: bioacoustic transects (open water)
	Weekly	Area	ROZE: target tows krill (open water) (Total Length, phycon, igr)
	Biweekly	–	RDUKEI: krill growth experiments
01 Oct-15 Nov	Once/2 days	Hu	Arrival chronology of breeding adults
01 Oct-15 Mar	Daily	Hu, To	Adult overwinter
			Age-specific survival/recruitment
01 Oct-15 Mar	Weekly	Li, Ch, Co	Adult overwinter
			Age-specific survival/recruitment
15 Nov-30 Nov	Once/colony	Hu, To, Li, Ch, Co	Breeding population size
15 Nov-30 Jan	Daily	Hu, To	Adult breeding chronology and success (chicks creched per pair)
05 Jan-02 Feb	Once/5 days	To	Chick diet composition & meal size
05 Jan-25 Feb	Daily	Hu	Adult foraging trip duration
15 Jan-30 Jan	Once/colony	Hu, To, Li, Ch, Co	Chicks creched per colony
01 Feb-25 Feb	Once/2 days	Hu	Chick weights at fledging
15 Feb-25 mar	Weekly/colony	Hu, To, Li, Ch, Co	Colony-specific breeding chronology

Table 2. LTER Palmer Even Log Overview Season 1998-1999

See table 1 for definition of standard sampling days. Events include particulate absorption (Ap), dissolve organic material analysis (Acdom), acoustics (bio-ac, Furuno 50kHz and Biosonics 120kHz), discrete chlorophyll analysis (chl), conductivity-temperature-depth (ctd, Seabird), high-performance liquid chromotography of phytoplankton pigments (hplc), instantaneous growth rate (igr), target tow for kirl (krilltarg, 50kHz), microscopic analysis of net plankton (net, >5µm), inorganic nutrient analysis (nuts), photosynthetically active radiation (par), physiological condition larvae (phycon), microscopic analysis of picoplankton (pico, 0.5-5.0µm), particulate organic carbon and nitrogen (chn), production phyotosysnthesis versus irradiance (Ppi), primary production simulated-in-situ (Psis), profiling radiometer (prr&puv, BSI), transport exopolymer particles (tep), and SCUBA diving (dive). Operations take place at LTER stations A, B, E, F, J, Sea-water-intake (SWI), Palmer dock, and Hero Inlet.

Event no.	**Month**	**Day**		**Year**	**Sampling day**	**bio-ac**	**ctd/prr/ puv/chl**	**Ap/ Acdom**	**hplc/ nuts/chn**	**net Ppi**	**Psis**	**tep**	**krilltarg**	**phycon**	**igr**	**Comments**
		Beg	End													
1	10	1	–	98	–	–	–	–	–	–	–	–	–	–	–	Arrive Palmer
10	10	14	15	98	1	–	–	–	A	A	–	A	–	–	–	–
19	10	16	19	98	1234	–	–	B	B	B	B	B	–	–	–	–
39	10	20	23	98	1234	Ajanus	E,B	E,B	B,E,B	B,E	E,B	B,B	–	–	–	Furuno
82	10	24	25	98	12	–	–	–	SWI	SWI	–	–	–	–	–	–
90	10	26	28	98	123	DF,FJ	–	–	SWI	SWI	–	–	–	–	–	Furuno
100	10	29	1	98	1234	–	–	–	SWI	SWI	–	–	–	–	–	–
111	11	2	5	98	1234	–	E,B	E,B	SWI,E,B	SWI,E	E,B	B	–	–	–	–
151	11	6	8	98	123	–	–	–	SWI	–	–	–	–	–	–	–
160	11	9	11	98	124	–	–	–	SWI	–	–	–	–	–	–	–
168	11	12	15	98	1234	–	B	B	B	B	B	B	–	–	–	Dive1-5; ship *LM Gould*
190	11	16	18	98	123	–	–	SWI	–	–	–	–	–	–	–	–
204	11	19	21	98	123	–	–	SWI	–	–	–	–	–	–	–	Dive6:dock; Dive7:Hero

Event no.	Month	Day		Year	Sampling day	bio-ac	ctd/prr/ puv/chl	Ap/ Acdom	hplc/ nuts/chn	net Ppi	Psis	tep	krilltarg	phycon	igr	Comments
		Beg	End													
217	11	22	25	98	1234	–	B	B	B	B	B	B	–	–	–	–
239	11	26	27	98	12	–	–	–	SWI	SWI	–	–	–	–	–	Dive8:Hero
249	11	28	31	98	1234	–	B*	B*	C,B	B	B	B	–	–	–	–
274	12	1	3	98	123	–	–	–	SWI	SWI	–	–	–	–	–	–
283	12	4	6	98	123	–	–	–	SWI	SWI	–	–	–	–	–	Dive9:Hero
294	12	7	9	98	123	–	–	–	SWI	SWI	–	–	–	–	–	–
304	12	10	13	98	1234	–	–	–	B	–	–	B	–	–	–	Dive10:Hero
319	12	14	16	98	123	–	–	–	SWI	–	–	SWI	–	–	–	Dive11:Hero
332	12	17	18	98	12	EJ,EA	B,E	B,E	B,E	–	B	B	–	–	–	Dive12:Hero; Furuno
361	12	19	21	98	123	–	–	–	E	–	E	–	–	–	–	–
376	12	22	24	98	123	–	B	B	B,E	–	B,E	B	–	–	–	–
409	12	27	29	98	123	–	E,B*	E,B	E,B	–	E,B	B	–	–	–	–
442	12	30	1	99	123	–	E,B	E,B	E,B	E,B	E,B	B	–	–	–	–
477	1	2	2	99	1	–	E,B	E,B	E,B	E,B	E,B	B	–	–	–	–
	1	8	8	99	–	EA,FJ	–	–	–	–	–	–	–	–	–	LTERJAN99 begin; BioSonics
	1	23	23	99	–	EB,FJ, FJ	B,E	B,E	B,E	B,E	B,E	–	–	–	–	cruise; BioSonics
	2	11	11	99	–	JF	E,B	E,B	E,B	E,B	E,B	–	–	–	–	cruise; BioSonics
	2	12	12	99	–	EA	E,B	E,B	E,B	E,B	E,B	–	–	–	–	BioSonics; LTERJAN99 end
517	2	16	18	99	123	EA,FJ	E,B	–	E,B	E,B	E,B	B	–	–	–	BioSonics
549	2	19	21	99	123	FJ	E,B	–	E,B	E,B	E,B	B	–	–	Dip	BioSonics

Event no.	Month	Day		Year	Sampling day	bio-ac	ctd/prr/ puv/chl	Ap/ Acdom	hplc/ nuts/chn	net Ppi	Psis	tep	krilltarg	phycon	igr	Comments
		Beg	End													
															Net	
581	2	22	25	99	1234	–	E,B	–	E,B	E,B	E,B	B	–	–	–	–
612	2	26	1	99	1234	EA,FJ	E,B	E,B	E,B	E,B	E,B	B	–	–	–	BioSonics
649	3	2	4	99	123	EA	E,B	E,B	E,B	E,B	E,B	B	E	–	–	BioSonics; targ.tow salps
687	3	6	6	99	1	FJ	–	–	–	–	–	–	–	–	–	BioSonics

Each line in table 2 represents one cycle of planned sampling. Acoustic transects, hydrographic and optical profiling, absorption profiling phytoplankton sampling, targeted krill tows for physiological condition and instantaneous growth rate experiments are given in separate columns.

There were various changes from past seasons in the sampling program both due to limitations in time, personnel and scheduling as well as due to focus on specific new queries. With six to eight LTER personnel on station for the 1998-99 season (2 to 3/Vernet; 1 to 2/Smith; 0 to 2/Ross/Quetin; 1 to 2/Fraser), zodiac sampling included 2 stations per cycle instead of 4 for hydro-bio-optics and for phytoplankton. Water column sampling was usually performed between 1200 and 1400 GMT with 5 l go-flo bottles capturing samples at light depths of 100%, 60%, 30%, 10%, 5% and 1%.

Chlorophyll analysis on phytoplankton samples was run in replicate using 0.45 micron filters, and the >20 micron phytoplankton fraction was sampled at the 60% light level (ranging from 2.0 m to 7.5 m). Palmer station work with Turner Designs chlorophyll solid standards was part of an investigation into verification of methods for fluorometer calibration. There was a special focus this season on investigation of the water column absorption of particulate (Ap) and dissolved (Acdom) material with additional filtering performed for spectrophotometric analysis. Two optical instruments measuring visible and ultraviolet radiation (PRR and PUV) were packaged together with foam fins in order to permit simultaneous deployment from a zodiac in free-fall mode. The CTD calibration was carefully documented since no salts were run.

The hardware and software for HPLC analysis remained the same as last year, and samples up to and including the January cruise were analyzed during the month of January. Nutrient samples were shipped to the University of California Santa Barbara Analytic Facility for analysis. Core data collection for production (SIS) continued through the season, and water collection was increased in order to facilitate a study on temperature effects on production.

Due to ship scheduling and equipment issues, personnel for the LTER Palmer Krill Component were on station during two separate periods: November 10 – December 22 and February 14 - March 13. Spring pre-cruise ice conditions prohibited standard acoustic transects or target tows for krill.

During the 1998-1999 USAP season, ice remained in Arthur Harbor through November so samples were taken for analysis from the station seawater intake during this period. A one day window of opportunity on the research ship *Laurence M. Gould* on 12 November made it possible to sample at Station B during the period that Arthur Harbor was iced in. Very limited boating was possible until mid-December when sampling from zodiacs began on a regular basis. This local situation with ice contrasts with the Peninsula at large, which experienced below average ice. The peninsula's below average ice started the preceding winter and continued into the spring/summer. This ice development differs significantly with that of both the spring/summer of 1995-1996 and of 1997-1998, which were preceded by an above average winter of ice with pack ice, yet ice began to clear from the nearshore Palmer region in mid-November.

An overview of the season is provided by preliminary data showing seasonal progression in selected parameters through the spring and summer (figure). The early part of the season surface water samples were taken both from the seawater intake as well as from shore at Bonaparte and Gammage Point. This alternate sampling continued through the season. The 1998-1999 season showed generally low chlorophyll biomass nearshore with small surface phytoplankton blooms of 5-10 mg/m3 beginning in November although values remained < 2 mg/m3 in December. The subsurface chlorophyll max was found between 5-10 m with an average value in December of 1.0 mg/m3. Absorption due to dissolved organic material of < 0.2 micron size was found near Palmer to be very low with an average absorption at 305 nm of 0.28 per m with values ranging from 0.23 per m to 0.46 per m at Stations B and E. Absorption increased when samples were taken in the presence of sea ice. In these circumstances, indications of the presence of ultraviolet protective pigments were also found.

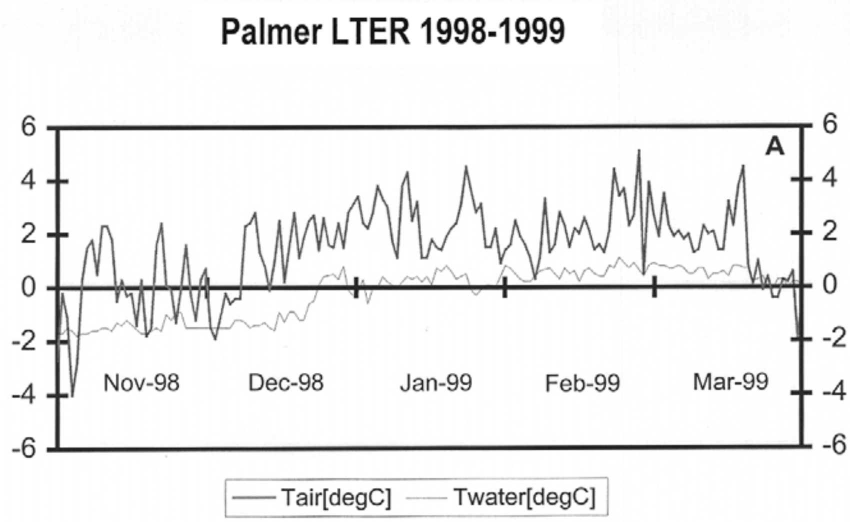

Figure 1a: Air temperature [degrees C] (heavy line) and water temperature [degrees C] (dashed line) at Palmer Station for the 1998-1999 season.

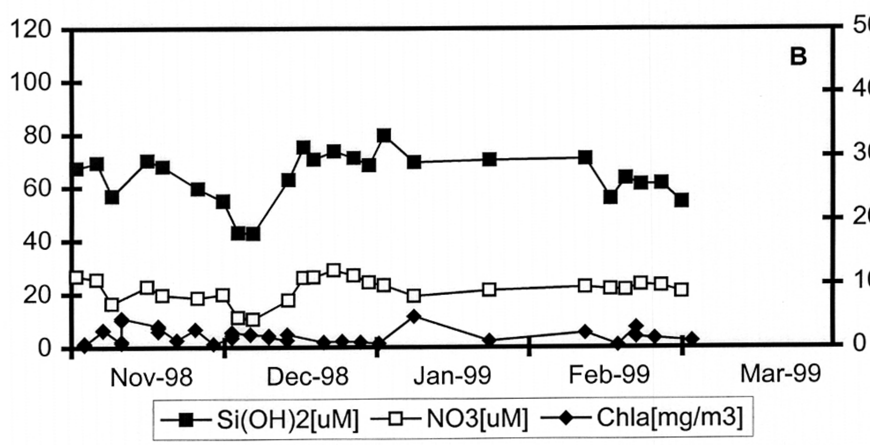

Figure 1b: Surface chlorophyll [mg/m3] (filled diamonds) with the scale to the right as well as nitrate [microMolar] (open squares) and silicate [microMolar] (filled squares) with the scale to the left for the 98 99 season at Station E in addition to Seawater intake samples when boating was closed due to ice in November-December time period.

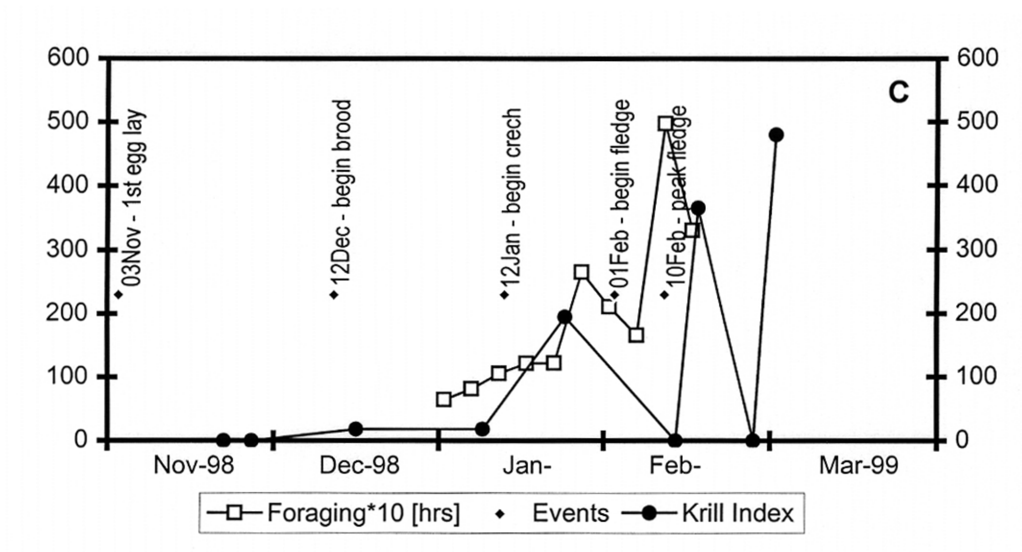

Figure 1c: Adélie penguin foraging [hours] (filled squares). Arrows indicate day of first egg laying, first brood, first creche, first fledging, and peak fledging at Humble Island for the 1998-1999 season. Also plotted is an "index" of krill biomass consisting of the areal extent of schools per km.

A total of 19 acoustic transects were conducted in the area near Palmer Station between 10 November 1998 and 12 March 1999, 9 between stations A and E, and 10 between stations F and J. As the data were collected, the depth and vertical dimensions (meters), the horizontal dimension in mm on the computer screen, and color of each aggregation were noted. The color is based on the density of acoustic biomass in the aggregation. An index of acoustic biomass was estimated from the dimensions and color data. Acoustic biomass was at undetectable levels in November and December 1998 during acoustic transects conducted with the Furuno echosounder (50 kHz). Transects were only possible on 3 days due to ice conditions. During 12 SCUBA dives under the ice, a few scattered individuals were seen, but aggregations of adult and larval krill were not observed. Acoustic biomass was still very low in early January, increasing in late January. Of the four transects conducted from mid-February to early March, no krill were found on two days, but large amounts on the two other days. In late February when krill were not found, many salp chains were seen floating at the surface.

Reproductive events associated with breeding chronology of Adélie penguins on Humble Island this season (Fraser et al. 1999) are noted by arrows in figure c. The Adélie penguin breeding population size, a measure of winter survival, decreased by 14.7% relative to the past season while the per-pair breeding success of these penguins dropped to 1.49 chicks creched per pair, or a decrease of 6.0% relative to the 1997-98 season. The decrease in breeding success of 0.09 chicks per pair is not statistically significant. Breeding chronology was slightly advanced relative to last year while mean fledging weights were unchanged.

The sampling event log, participant list and other project information for the season are available online (http://www.icess.ucsb.edu/lter). Acknowledgement and thanks are given to members of the Palmer LTER research team and of Antarctic Support

Associates. This material is based upon work supported by the National Science Foundation under Award No. OPP-9632763 with additional funding provided by the Regents at the University of California.

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Palmer LTER: Seasonal process sea-ice cruise, June-July 1999 (NBP99-06)

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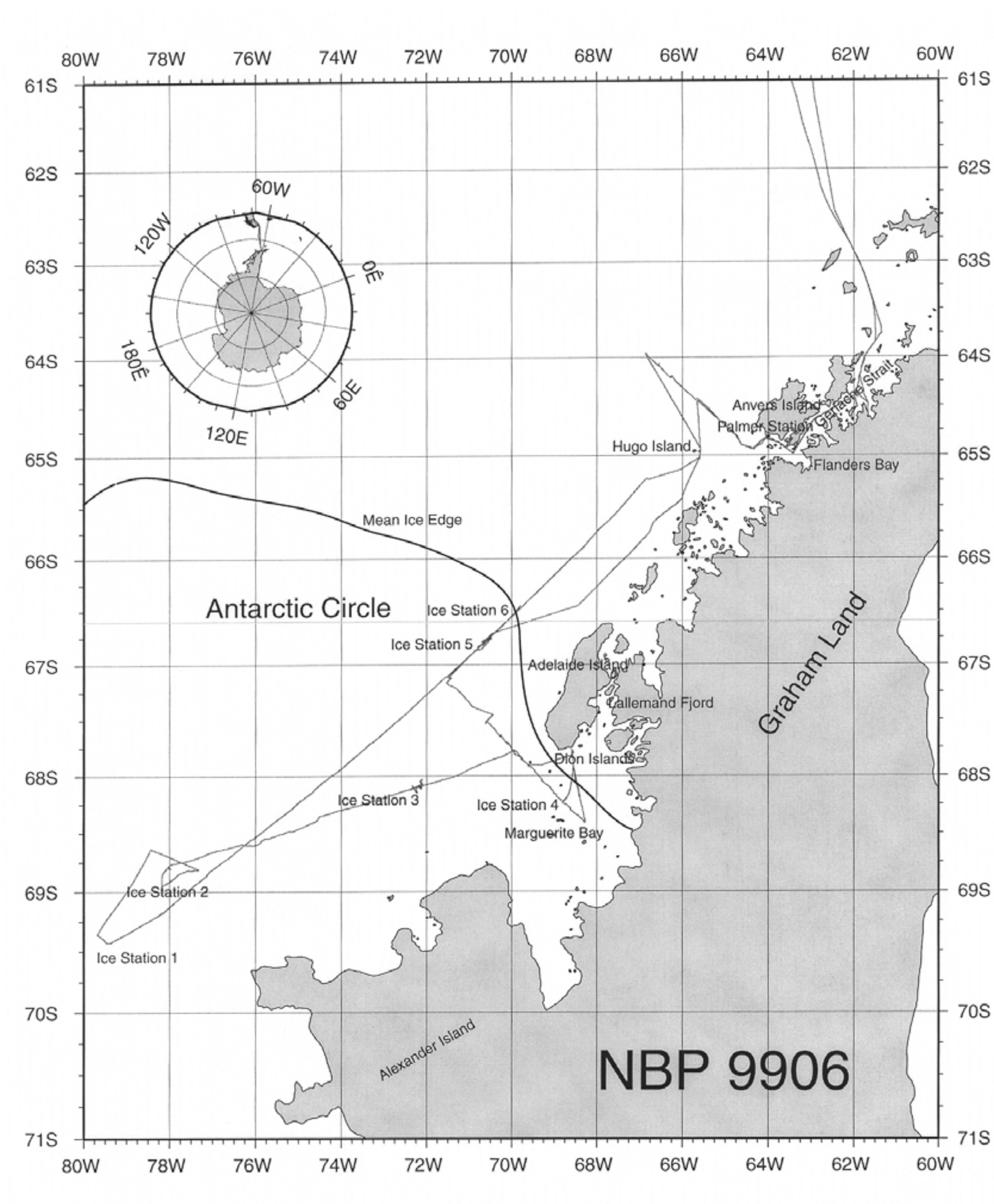
The overall objective of the Palmer Long-Term Ecological Research (PAL LTER) early winter sea-ice cruise (NBP99-06, 11 June-15 July 1999) was to investigate and understand sea ice growth processes and the relationship of these processes to the biota during the period of sea ice growth. We made physical, optical, chemical and biological observations in representative sea ice stages including open water, frazil, grease, nilas, pancake and young first year sea ice as the ship transected from the marginal ice zone into close pack ice.

Key goals of the Palmer LTER sea ice cruise were to study

1. processes associated with sea ice formation, linkages between the various stages of sea ice growth and the associated biological, chemical, optical and physical characteristics, and
2. winter abundance and distribution of Adélie penguins in association with sea ice habitat.

The research ship *Nathaniel B. Palmer* crossed the ice edge on June 18 at 66º 22.00 S and 69º 32.00 W and continued heading south approximately 540 km. Near our most southern location, three ice buoys were deployed in 10/10 pack ice in a 100km triangular array for Dr. Hartmut Hellmer (Alfred-Wegener Institute, Bremerhaven). On our return, transect back to the ice edge a series of multi-day stations were held in various sea ice regimes. Sea Ice Station #1 was held initially in closely packed deformed first-year sea-ice that had a mean thickness of 53cm. By the end of our second day on this station, a long-period swell was visible in the pack ice, and by the third day at this station, the swell had increased such that the 100-500m floes had been broken up into 10-50m floes. Sea Ice Station #2 was held for 5 days in closely packed deformed gray-white sea-ice with mean thickness of 27cm and floe sizes 100-500m. During the middle of this 5-day period, we experienced a warming from -18C to -5C and a drift speed of 2-3 knots. Ice Station #3 was occupied for 3 days in open pack ice that consisted of gray and gray-white sea-ice with mean thickness of 22cm and floe sizes of 20-100m.



NBP99-06 cruise track showing the locations of the ice stations, the mean ice edge, and the transects in/out of the pack ice with respect to the ice edge.

A deviation was made from our north-easterly transect (i.e., parallel to the Antarctic Peninsula) that involved a south-easterly transect along our 200 line into Marguerite Bay. Here we successfully deployed a landing party at Dion Island to carry out a sea bird census in this Special Permit Area (SPA), which is the most northern location of an emperor penguin colony. There we also held Ice Station #4 in brash/young ice conditions where we observed and sampled nilas over a 2-day period. Returning to our north-easterly transect, stations five and six were held within 20-40km of the ice edge. At Ice Station #5 we encountered rounded cake ice (20cm thick, 1-2m diameter) heavily topped with flooded slush and surrounded by a thick slurry of floating slush (10-15cm thick). Both the rounding of the cakes and the slush were presumably caused by the swell-induced jostling of cakes against each other. At Ice Station #6 we observed very young pancake ice, 0.5-2 cm thick and 10-20 cm in diameter. We crossed the ice edge back into open water on July 6 at 66º 29.48 S and 69º 50.89 W. During our 18 days in the seasonal sea ice zone, the ice edge had advanced and retreated several times (as indicated by satellite imagery), but by the time we exited it, it was within 20km of where we first encountered it. Note that the location of the ice edge for this time of year was at least two degrees south of where it can be found during an average sea-ice extent year. Table 1 summarizes the ice station information.

Table 1. Summary of Ice Stations on LTER Cruise NBP99-06

Ice state	Grid location	Dates (jd)	Ice type sampled	Sea ice conditions	Mean thickness (cm)
1	-220.100	171-173	fy/deformed fy	close pack	53
2	-100.100	173-177	grey-white/fy	close pack	27
3	100.040	178-180	grey/grey-white	open pack	22
4	200.-100	182-183	nilas	dynamic/miz	2
5	280.100	186	old pancake	miz	20
6	300.100	187	young pancake	miz/ice edge	2

The science activities at these stations included:

1. snow/ice transects (either by foot in close pack ice or by zodiac in open and young sea-ice) for snow depth, snow-ice interface temperature and ice thickness and freeboard;
2. ice cores or blocks for physical analysis (temperature, salinity, delta18O and stratigraphy);
3. ice cores and/or blocks for chemical and biological measurements (PC, PN, PP, P-Si, DOC, DON, DOP, inorganic nutrients, bacteria and phytoplankton biomass, photosynthetic pigments, taxonomic composition and potential primary production);
4. CTD (temperature, conductivity, depth, transmittance, O2, fluorescence and water samples for LTER core measurements);
5. optical observations (profiling reflectance radiometer, spectral radiometer for light transmission through snow & ice);
6. 1 m net zooplankton tows and diver observations beneath the ice for collection of krill and larvae; and
7. sea bird observations.

This is the third seasonal process cruise for the Palmer Long-Term Ecological Research (PAL LTER), which together with seven annual January cruises, adds to our growing observation of the area west of the Antarctic Peninsula (Smith et al., 1995; Ross et al, 1996). In addition to the six multi-day ice stations, we held stations along the 200 and 600 LTER cardinal lines perpendicular to the coast as well as along a line 100km from the coast but parallel to the WAP as we transited in/out of the sea ice. During our in/out transits we made two unsuccessful attempts to go ashore to repair the AWS unit on Hugo Island. Tables 2a and 2b summarize the chronology and sampling division of the cruise, respectively.

Table 2a. Overview of the LTER Cruise NBP99-06 where the day of the month and activities are listed including LTER grid locations (xxx.xxx) and ice station number. Activities while at an ice station included ice sampling for physics and biology, ice/snow depth transects, CTD, optics, dives for zooplankton, nets, and bird observations.

Date	Activity
June	
11	Punta Arenas depart, Transect, Straits of Magellan
12	Transect, Drake Passage, BirdObs
14	Transect, Drake Passage, BirdObs, ATChl
13	Transect, Drake Passage (rough weather)
15	Gerlache Strait, BirdObs, Dive(Training), ATChl
16	Palmer Station, CTD(600.040), Dive(Training)
17	CTD(600 line & 500.100), BirdObs, 1mNet(500.100), HugoAWS (abort)
18	CTD(xxx.100, 400 to 150), BirdObs, IceEdge, Optics, IceSample
19	CTD(xxx.100, 100 to -100), BirdObs, lmNet(-50.100), Drifter#1
20	CTD(-160.100), 1mNet, Drifter#2, IceStat#l(-220.100)
21	IceStat#l(-220.100)
22	Drifter#3, IceStat#2(-100.100)
23	IceStat#2(-100.100)
24	IceStat#2(-100.100)
25	IceStat#2(-100.100)
26	IceStat#2(-100.100)
27	IceStat#3(100.040)
28	IceStat#3(100.040)

Date	Activity
29	IceStat#3(100.040)
30	CTD(200 line, 000 to -070), BirdObs
July	
01	CTD(200 line, -080 to -100), BirdSurv(Dion Is), IceStat#4(200.-100)
02	IceStat#4(200.-100), BirdSurv(Dion Is)
03	IceStat#4(200.-100), BirdSurv(Ginger Is), CTD(200 line, -020 to -010)
04	CTD(200 line, 000 to 100, 240.100), BirdObs, MocNet
05	IceStat#5(280.100)
06	IceStat#6(300.100), CTD(260.100), BirdObs, Optics, MocNet, IceEdge
07	CTD(xxx.060, 350 to 550), MocNet, BirdObs, HugoAWS (abort)
08	CTD(600 line, 200 to 140), 1&2mNets, BirdObs, Optics
09	XBT(600.040), bad weather
10	Palmer Basin, bad weather
11	Gerlache Strait
12	Transect, Drake Passage
13	Transect, Drake Passage
14	Transect, Straits of Magellan
15	Punta Arenas arrive

Table 2b. Summary of Events on LTER Cruise NBP99-06

Parameter	Number of events	Number of days per event	Number of days	Percentage of cruise time
CTD transect	101	0.069	7	20.0
Ice station 1	19	0.105	2	5.7
Ice station 2	57	0.088	5	14.3
Ice station 3	26	0.115	3	8.6
Ice station 4	13	0.231	3	8.6
Ice station 5	5	0.200	1	2.9
Ice station 6	4	0.250	1	2.9
AWS Hugo	2	0.500	1	2.9
Tests	3	0.677	2	5.7
Weather	2	1.000	2	5.7
Transect	8	1.000	8	22.9
Total	239	—	35	100.0%

The life histories of various polar marine species are synchronized with the seasonality of sea ice. Thus any temporal shifting of the annual cycle or regional sea ice coverage will significantly change the physical environment of any given season and, consequently also affect those ecosystem variables that are timed to the mean annual cycle of sea ice. In the WAP area the mean annual cycle is characterized by a relatively short (about 5 months) period of ice advance, with peak ice extent occurring in August, followed by a longer period (about 7 months) of sea-ice retreat. However, there is also significant interannual variability about the mean, and in 1999 sea ice reached maximum extent one month later, had a short peak duration and retreated rapidly. It is within this context of a late and short winter that the NBP99-06 Sea Ice Cruise was conducted.

As part of the Palmer LTER Education Outreach, Ms. Dominique Sonier, a middle school teacher from Santa Barbara, was aboard ship. She communicated to online classrooms through real time field reports and photographs posted on the World Wide Web.

This research cruise was composed of the Palmer LTER research team including team leaders E.Woehler (Fraser, BP-013), M.Vernet (Vernet, P-016), D. Martinson (Martinson, BP-021), L.Quetin (Quetin/Ross, BP-028), R. Smith (Smith, BP-032), and D. Karl (Karl, BP-046). Special thanks to the Palmer LTER research team members, to the

Antarctic Support Associates and especially to Captain Joe Borkowski and his exceptional crew aboard the RESEARCH SHIP Nathaniel B. Palmer, all of whom made this a most successful and memorable research cruise. This material is based upon work supported by the National Science Foundation award OPP 96-32763 with additional funding provided by the Regents at the University of California.

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Palmer LTER: Microscopic analysis of ice assemblages in new-year sea ice in the Western Antarctic Peninsula, June-July 1999

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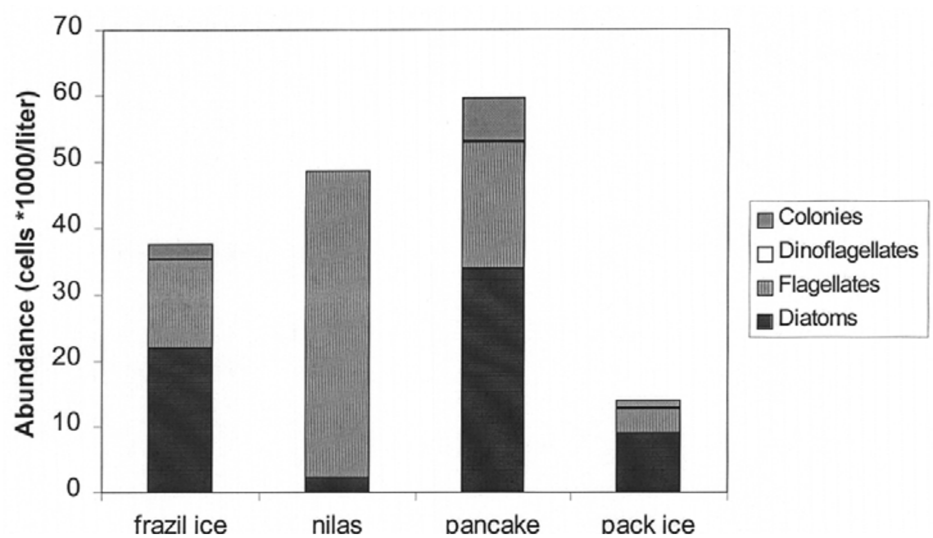
The LTER program is testing the hypothesis that the annual advance and retreat of the sea ice affect the structure and function of the marine antarctic coastal ecosystem West of the Antarctic Peninsula.

Microalgal growth is observed both in sea ice (epontic algae) and in the water column (phytoplankton). In winter, when seawater freezes, the microalgae are incorporated and concentrated in the developing ice from the water column (Garrison et al. 1983). Ice microalgal communities in the Scotia, Weddell, and Ross seas show high biomass with important contribution to annual primary production as well as a characteristic assemblage (Horner, 1985; Spindler, 1994). Hypothetically, in the following spring, these algae modify water-column populations by seeding the mixed layer during ice melting (Garrison, et al. 1987). An unknown amount of the yearly productivity in the western Antarctic Peninsula area is due to the development of ice microalgae. Two winter cruises were scheduled to estimate winter abundance, biomass, and total primary productivity due to seasonal sea ice microalgae and phytoplankton and to characterize the assemblages responsible for this production.

During the first of these cruises, sampling was done in the western Antarctic Peninsula between 64º-70º S and 62º-80º W, from 17 June and 8 July 1999, aboard the U.S. research ship *Nathaniel B. Palmer* (Smith and Stammerjohn this issue). Stations visited included open water, medium and thin pack ice, and pancake, frazil and nilas ice. Water-column samples were taken from surface to bottom with 10-liter Niskin bottles attached to the CTD rosette. Sea ice was collected with buckets or with an ice-coring auger. Ice samples were melted in large volumes of filtered seawater (roughly in a ratio of 1:3). One liter aliquot of sample (seawater or melted ice) was concentrated through 0.8 micrometer membrane filter and analyzed under a fluorescent microscope (Booth 1993). At least 300 cells were counted whenever possible, otherwise the whole filter was analyzed. Samples for qualitative analysis were collected and preserved with Lugol's iodine in order to improve the taxonomic determination of cells.

The winter microalgal community was composed mainly of diatoms and unidentified phytoflagellates. Overall, diatoms were dominant in the ice samples and phytoflagellates in the water column. Total cell abundance was low in all the stations, nevertheless an elevated diversity of species was found. In surface waters the cell concentration was about one order of magnitude lower than in the summer (between 2-6 x 10^4 cells per liter) (Smith, et al. 1996). The maximum development of the phytoplanktonic populations was found in near shore waters with young sea ice coverage (frazil ice, pancakes, or nilas), and the lower concentration in waters with pack ice coverage. The abundance of ice microalgae populations varied with ice type: pack ice presented the lower abundance of cells (average 14 x 10^3 cells per liter) and pancake ice the highest (60 x 10^3 cells per liter) (figure). Also, the composition of algae varied with ice type: in ice formed under turbulent conditions (frazil, pancake and pack ice), diatoms were more abundant than phytoflagellates. The exception was the assemblage associated with nilas, where flagellates dominated over diatoms.



Average microalgae abundance in different ice types in the Western Antarctic Peninsula during June and July 1999.

Phytoflagellates consisted mainly of <10 micrometer forms and were present in colonies in various stations. An elevated diversity of diatoms species was found, both in the water column and in the ice. The ice diatom assemblage was dominated mostly by pennates; centric diatoms dominated in only a few instances. Pennate diatoms include cells between 10 um and 100 um, also larger forms (> 800 micrometers) as in the case of *Trichotoxon reinboldii*. Diatoms present in most of the ice samples belonged to the genera *Chaetoceros*, *Membraneis* and *Fragilariopsis* and *Proboscia truncata* and *Corethron criophilum*. Specimens of the genus *Asteromphalus*, cited as benthic, were also present. Some dinoflagellates were found in a few stations, but were not numerically abundant.

Some diatom cells presented winter morphological structure (for example *Proboscia truncata* and *Eucampia antarctica* var. *recta*), and others presented resting spores, such as *Chaetoceros socialis*. However, in the young ice sampled, *E. antarctica* var. *recta* was found in the summer stage. The winter microalgal community was not a resting assemblage since cells from the genera P*roboscia*, *Eucampia*, *Fragilariopsis* and *Chaetoceros* were dividing.

In conclusion, the phytoplanktonic community was an order of magnitude less abundant than in the summer. The ice microalgae, found in new-year ice, represented an important contribution to the abundance and diversity of the winter microalgal community of the area. Ice samples showed a characteristic taxonomic composition, with planktonic and benthic forms. These results agree with those found by Garrison et al. (1987) for the Scotia Sea, although our samples are qualitatively different from those of other areas of the Southern Ocean where *Fragilariopsis* spp. dominate numerically. Both phytoflagellates and diatoms seem to be incorporated in ice, but apparently diatoms are more successful in this habitat and constitute an actively growing population.

We thank the support of the officers and crew of the *Nathaniel B. Palmer*, the personnel from Antarctic Support Associates and the scientists on the cruise for their help and support in sampling and analyses. This project was supported by the Office of Polar Programs, National Science Foundation, grant NSF OPP 96-32763.

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Palmer LTER: Teacher Experiencing Antarctica, January 1998

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Getting a teacher to Antarctica is not an easy task. After all, most expeditions to Antarctica occur during the school year when a teacher is active in the classroom. Moreover, why would anyone want to send a teacher there in the first place? Two National Science Foundation (NSF) organizations—the Office of Polar Programs (OPP) and the Directorate for Education and Human Resources (EHR)—committed to integrating science education and research by joining to send teachers to Antarctica as part of a research team. Since 1992, four to eight teachers, who are intensely interested in developing and using classroom activities based on polar research, have been chosen each year to be a TEA — Teacher Experiencing Antarctica or Arctic (http://tea.rice.edu/). Taking into account the teacher's expertise and interests, each TEA is matched with a research scientist. A one- to two-week internship at the researcher's home institution prepares participants for a subsequent field experience.

Figure 1. Besse Dawson adjusting oxygen sample bottles in water baths on the deck of the* Laurence M. Gould *(NSF/USAP photo by D. Karl, University of Hawaii).

Because of Besse Dawson's training in biology and teaching of high school biology and aquatic science, Dr. David Karl in the Department of Oceanography at the University of Hawaii was selected as her scientific mentor. Dr. Karl sent an assortment of abstracts and texts on studies of microbial activities in a variety of ocean regions were sent to give a solid content background in his particular studies. Subsequently, a two-week internship to Karl's laboratory provided the opportunity to discuss the group's research, observe and learn laboratory techniques, participate in design of an experiment and sail on a short research cruise. From this cruise, Ms. Dawson learned not only just how easy it is to get sea-sick but also about the ship-board environment and routine in preparation for an antarctic research cruise.

Dr. Karl is a member of the Palmer Long-Term Ecological Research (LTER) Program. The Palmer LTER conducts annual cruises west of the Antarctic Peninsula as part of a multi-component team effort to understand and document interannual change in the Southern Ocean ecosystem (Smith et al, 1995). The cruises are held during the austral spring to sample the polar system at a time of high water-column activity that coincides with penguin colony reproduction.

During the Palmer LTER January 1998 cruise (Karl and Baker 1998) aboard the research ship *Laurence M. Gould*. Ms. Dawson worked closely with Chris Carrillo, a doctoral candidate working with D. Karl. Dissolved oxygen was measured as an indicator of the productivity of the photosynthetic bacteria in the water. This year was a low-ice year. Corresponding low levels of dissolved oxygen were found in the water column, except in Marguerite Bay where levels were closer to those found in previous years.

Besides functioning as laboratory technicians, TEAs also perform a variety of teacher duties. Each day a journal entry is sent by electronic mail using the ship's satellite communications so students have rapid access to field news. The messages are sent to an email account from which they are posted routinely to a web page. Digital pictures frequently accompany these transmissions to visually describe the teacher's experience. They are posted in the journal entry as a low-resolution jpeg file to meet file size requirements (<30Kb) imposed because of the restricted time window of satellite communications from Palmer Station. The pictures are also assembled as a separate slide show.

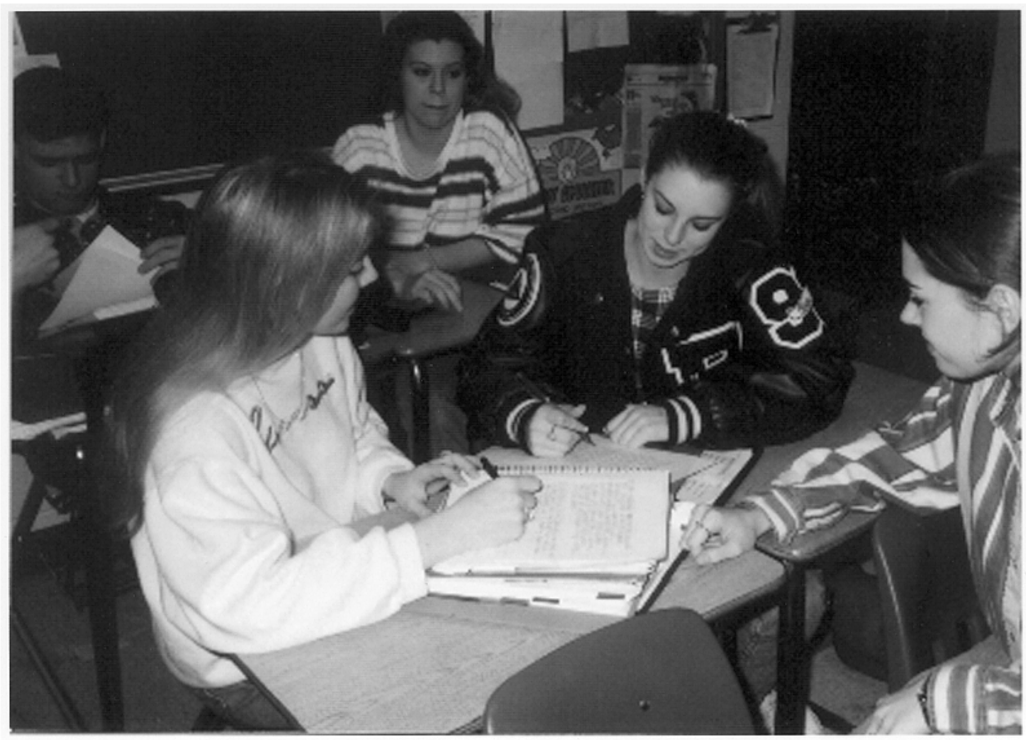

Figure 2: Pearland High School students engaged in Antarctic cooperative group activity (NSF/USAP photo by B. Dawson).

Responses to email questions from students and other inquirers are additional TEA responsibilities. Preparations for these communications often include interviewing research participants from principal investigators to support staff to volunteer undergraduates to better describe what is being studied and why. Interviews with the captain and crew were included to provide alternative perspectives on a research cruise and on how the ship functioned so independently.

Thus, TEAs are lab technicians, journalists, photographers, long-distance support staff for in-class substitutes, and typing encyclopedias for anyone with a question about Antarctica. Long days were not unusual so the extended sunlight in the polar summer is valuable in sustaining energy. The TEA experience does not end with the return to the classroom. Classroom activities continue to reflect Antarctic research currently being done in the field. Education activities, such as Dawson's "Secret Agent of Dissolved Oxygen" done in conjunction with the LTER researchers, are later developed and incorporate hands-on and inquiry-based approaches backed by strong scientific content. Presenting at conferences such as the National Science Teacher Association (Dawson, 1999) and developing curriculum materials in conjunction with GLACIER (http://www.glacier.rice.edu/) extends the awareness to others of studies currently taking place in Antarctica and of how teachers can bring such experience into their classrooms. Students, eager to study about science from such an exotic place, are better able to understand the relevance of polar studies even from this remote area.

The Palmer LTER continues to collaborate with Dawson through TEA teacher involvement in design of future LTER educational outreach activities. Thanks are extended to Dr. Stephanie Shipp who developed Besse Dawson's interest in Antarctic Science through collaborations on educational Antarctic research and to Dr. Wayne Sukow for his advocacy for the TEA program. Specific recognition goes to Dr. David Karl's research team for all their time and training. Thanks go to the entire LTER team, Antarctic Support Associates and ship Captain and crew who supported education as a part of the LTER January research cruise.

Finally, without the continual support from home, both by the Pearland Independent School District in general and by Robert Dawson in particular, this experience and subsequent outreach activities would not be possible.

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