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RACER: Primary production in Gerlache Strait, Antarctica, during austral winter

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The overall objective of this study, which was one component of the multidisciplinary research on antarctic coastal ecosystem rates (RACER) program (see Huntley et al. 1991), was to document the biomass and primary productivity of phytoplankton throughout the Gerlache Strait during the austral winter. Massive spring blooms have been reported previously in this coastal area (for example, Holm-Hansen and Mitchell 1991; Vernet, Letelier, and Karl 1991). Chlorophyll-*a* concentrations in the surface waters have been reported to be 20–25 milligrams of chlorophyll-*a* per cubic meter (mg chl-*a* m^{-3}) [500–700 milligrams of chlorophyll-*a* per square meter (mg chl-*a* m^{-2}) and estimates of daily rates of primary productivity within the euphotic zone have been 2–5 grams of carbon per square meter per day (g C m^{-2} d^{-1}). It is anticipated that the winter data reported in this article will provide sufficient baseline data to estimate the annual primary production more accurately in this otherwise well-studied area.

Field data were obtained on the R/V *Nathaniel B. Palmer* cruise between 11 July and 17 August 1992. Primary production experiments were performed with water collected from "fast" grid stations: FA58, FA57, FA46, FA38, FA30, FA08, and also from station A (Stn A) (the principal RACER time-series station). Discrete samples were collected 1–2 hours (h) before sunrise from 2, 5, 10, 15, 20, 30, 50, and 75 meters (m) by means of PVC Niskin bottles (equipped with Teflon-coated springs) mounted on an instrumented rosette. The rosette was equipped with sensors to measure conductivity, temperature, chlorophyll-*a* fluorescence, beam attenuation, and photosynthetically available radiation. Carbon uptake rates were measured by adding 10 microcuries (μCi) of sodium bicarbonate ($NaH^{14}CO_3$) to duplicate samples in 250-milliliter (mL) borosilicate glass bottles (with Teflon lids). After thorough mixing, the bottles were incubated for the duration of the light day (approximately 6 h) in simulated *in situ* deck incubators corresponding to the light levels from which the samples were taken (achieved with neutral density screening), and *in situ* temperature was maintained with continuously flowing near-surface sea water. Dark bottles were collected from 2 and 75 m, and the average radiocarbon counts were used for correction of nonphotosynthetic carbon uptake. Incubations were terminated by filtration [pressure differential less than 150 millimeters of mercury (mm Hg)] onto 25 mm Whatman GF/F filters and placed directly into scintillation vials, exposed to concentrated hydrochloric acid fumes for approximately 15 h, dried, and vented (for 8 h or more). The incorporated radiocarbon was then determined by standard liquid scintillation procedures, using a Wallac model 1409/11 liquid scintillation counter and Ecolume scintillation cocktail. Daily rates were calculated from hourly rates based on the portion of the light day (determined with a continuously recording Biospherical Instruments, Inc., quantum meter QSR-250) that the incubation period covered.

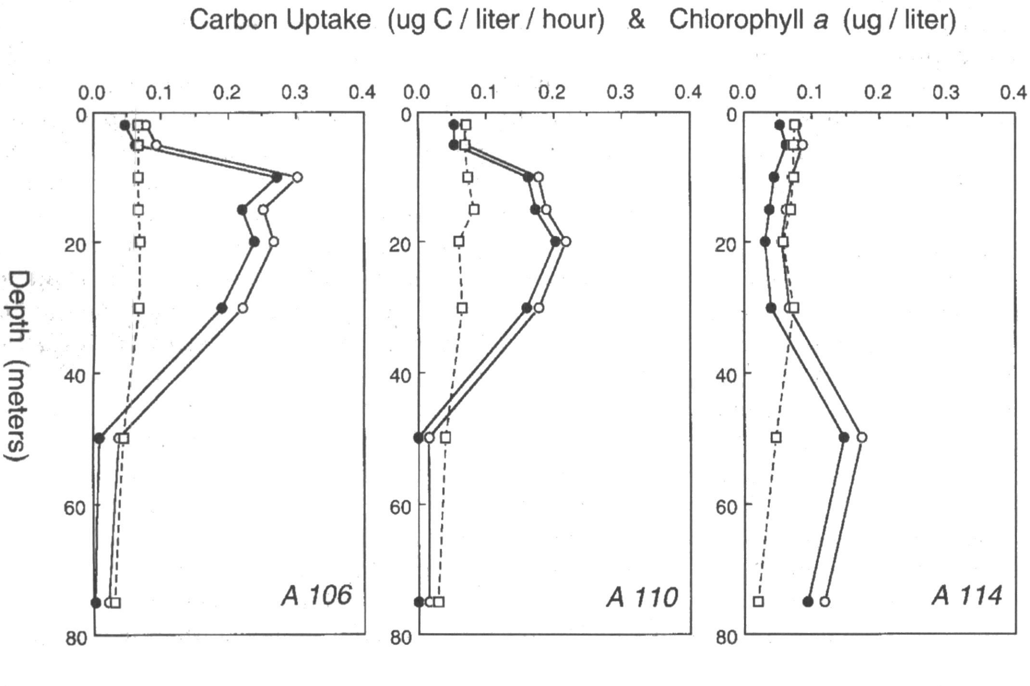
Samples for chlorophyll-*a* measurements (280 mL) were collected on 25 mm Whatman GF/F filters (pressure differential less than 150 mm Hg) and immediately extracted in 10 mL of absolute methanol (6 h in the dark at 4°C) according to procedures outlined in Holm-Hansen and Riemann (1978). After extraction, extracts were shaken, centrifuged, and fluorescence-measured before and after acidification in a Turner Designs model 10-005 fluorometer, recently calibrated with pure chlorophyll-*a* (Sigma Chemical Co.), whose concentration was determined by spectrophotometric analysis.

The concentration of chlorophyll-*a* in the surface waters throughout the RACER fast grid of Gerlache Strait was uniformly very low [0.03–0.07 micrograms per liter ($\mu g\ L^{-1}$)] and no subsurface chlorophyll maxima were observed during the July–August period of study. Integrated values of chlorophyll-*a* throughout the euphotic zone (0–75 m) were less than 5 mg m^{-2} (see table) suggesting very little phytoplankton biomass at this time. Rates of primary productivity were also very low with maximal values generally in the upper 30 m of the water column. A 3-day time-series of primary productivity experiments was conducted at Stn A which demonstrated that although the vertical structure of productivity varied somewhat, the integrated euphotic zone daily uptake remained constant (see table). The problem of correcting for nonphotosynthetic uptake of carbon during ^{14}C incubations has been a subject of continued debate in the literature because it is clear that nonphotosynthetic ^{14}C uptake may occur at very different rates in the light and dark (for example, Hecky and Fee 1981). In a recent review, however, Li, Irwin, and Dickie (1993) concluded that even in oligotrophic waters the question of whether to correct for dark uptake is of real concern only in the deeper areas of the euphotic zone, where photosynthesis is severely limited by light. During the antarctic winter, the availability of light for phytoplankton growth throughout the

Integrated values (0–75 m) of biomass (chlorophyll-a) and primary productivity (^{14}C-uptake) of natural phytoplankton communities in the Gerlache Strait, during austral winter

Station number	Location	Sampling date	Chlorophyll-*a* (mg m^{-2})	Primary productivity (mg $m^{-2}\ d^{-1}$)	
				A[a]	B[b]
Stn-A	64°10.8'S 61°20.6'W	17 July	4.11	49.9	63.9
Stn-A	64°11.7'S 61°19.7'W	18 July	3.98	34.8	41.7
Stn-A	64°10.6'S 61°18.5'W	19 July	4.11	35.6	46.5
FA-58	64°07.6'S 61°16.9'W	20 July	2.97	45.4	55.6
FA-57	64°58.7'S 60°42.8'W	21 July	2.40	12.0	44.6
FA-30	64°02.9'S 61°31.0'W	22 July	4.16	12.8	93.5
FA-46	64°12.5'S 61°56.2'W	23 July	3.93	15.6	44.5
FA-08	64°29.5'S 61°21.6'W	24 July	3.87	25.0	55.5
FA-38	64°12.7'S 61°10.9'W	26 July	2.33	59.6	131.1

[a]Reported rates are corrected for dark bottle uptake.
[b]Reported rates are not corrected for dark bottle uptake.



Vertical distribution of chlorophyll-*a* concentration and carbon uptake by natural phytoplankton assemblages at Stn A—the principal RACER time-series station—on 17 July (A-106), 18 July (A-110), and 19 July (A-114) 1992. Closed and open circles represent dark-corrected and uncorrected ^{14}C uptake rates, respectively. Open squares represent chlorophyll-*a* concentration. (ug denotes micrograms.)

water column is severely limited both by the declination of the Sun and the shortened daylight period (approximately 6 h), and it is likely that heterotrophic processes dominate in this nutrient-rich environment during this time. We have reported both uncorrected and dark-corrected hourly rates (see figure) and also daily rates of primary productivity (see table); the integrated (0–75 m) water column rates are slightly higher than the low values found by Brightman and Smith (1989) for the Bransfield Strait during June (approximately 7 mg C m^{-2} d^{-1}), but show that primary productivity during this season is relatively minor. These results clearly demonstrate the oligotrophic nature of the coastal waters of the Gerlache Strait during austral winter.

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RACER: *Euphausia superba* in Gerlache Strait, Antarctica, springs of 1989 and 1991

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Various degrees of spatial separation of age or size groups of *Euphausia superba* have been frequently reported, particularly with respect to maturing and mature sizes (see, for example, Brinton and Antezana 1984; Siegel 1988). There were, however, particularly puzzling characteristics of population groups and their distributions during the first research on antarctic coastal ecosystem rates (RACER) program, 1986–1987, in the region of Bransfield Strait (Brinton 1991). These characteristics raised questions as to place of origin and parental stock of abundant larvae in the northern Gerlache Strait. Sampling during the course of the season, December–March, indicated that there had been intense larval recruitment associated with a strong December–January phytoplankton bloom in a warm (2–3°C) pool of Gerlache water. Experiments showed larval growth to be more rapid in Gerlache larvae than in Bransfield larvae, many of which had apparently been transported from the Gerlache center (Huntley and Brinton 1991). We found no evidence, however, of adult *E. superba* at or near the Gerlache sampling stations at any time.

Collecting during the 1989 season (November) was by two methods: (1) a 1-square-meter MOCNESS, with either eight or nine nets sampling at intervals to 300 meters (m) depth and an additional net sampling 0–300 m and (2) a 1.25-m ring-net (without bridle), also towed obliquely to 300 m. MOCNESS catches were larger by night than by day but differed insignificantly from day or night ring-net catches. In 1991, only the MOCNESS was used. For the preliminary information presented here, integrated numbers of krill from the MOCNESS serial nets (night) were combined with the corresponding 0–300-m samples from MOCNESS and the ring-net (day and night). Krill were measured tip of telson to tip of rostrum. Study of *E. superba* and other euphausiid species during the two seasons in Gerlache Strait is still in progress, together with analyses of certain zooplankters including abundant larvae of the prawns *Chorismus antarcticus* and *Neocrangon antarcticus.* Gaining understanding of relationships of environment with species recruitment during spring bloom to early January is one of the objectives of RACER II and III.

Paths traced by drift drogues monitored during RACER II, November 1989, together with geostrophic calculations, confirmed that a northeastward current flowed through the western Gerlache, giving rise to branches extending across Bransfield Strait to the north (Niiler, Amos, and Hu 1991, and later data). These branches either merged with the Antarctic Circumpolar Current north of Livingston Island or, south of King George Island, turned southwestward, flowing back along the