Korean Journal of Polar Research
Volume 4(2): 67-72, 1993

Primary Food Sources for Shallow-water Benthic Fauna in Marian Cove, King George Island during an Austral Summer

Ahn, In-Young, Jae-Shin Kang and Sung-Ho Kang

Polar Research Center, Korea Ocean Research & Development Institute, Ansan P.O. Box 29, Seoul 425-600, Korea

Primary food sources for benthic fauna were investigated in an Antarctic nearshore water (<30 m) in King George Island in February of 1993. The suspension-feeding bivalve *Laternula elliptica*, one of the most common infauna in the Antarctic nearshore waters, was chosen as a species representing the benthic communities. Algal composition was microscopically analyzed in the ambient seawater, trap sediment, *Laternula*-inhabiting sediment and gut content during a 16-day period. Benthic diatoms comprised the majority of the microalgal biomass in all samples, but algal composition varied considerably among samples. *Synedra* spp. and *Licmophora* spp. were the most dominant diatoms in the surface water and in the trap sediment. In particular, *Synedra* spp. (62-100%) predominated in the seawater throughout the 16-day period. On the other hand, surface sediment of *L. elliptica* habitat was dominated by *Biddulphia* spp., *Trachyneis aspera* and *Cocconeis* spp. In the gut content, *Cocconeis* spp., *Licmophora* spp. and *Trachyneis* sp. were abundant. Thus the dominant diatom species in water column and bottom sediment were also found as major gut content of *L. elliptica*. The results of this study suggest that benthic diatoms may be utilized as primary food source by benthic fauna in the Antarctic nearshore waters when other food sources are not available.

Key words: benthic infauna, food, benthic diatom, species composition and density, nearshore

INTRODUCTION

Water column production and sedimentation of planktonic microalgae have been considered as primary processes providing food to benthic fauna. In many coastal waters, suspension-feeding bivalves are important phytoplankton consumers and thus play an important role in the coupling of pelagic and benthic ecosystems (Hargrave, 1973; Nixon *et al.*, 1975; Flint and Kamykowski, 1984; Murphy and Kremer, 1985; Doering *et al.*, 1986; Kautsky and Evans, 1987; Loo and Rosenberg,1989; Sornin *et al.*, 1990; Dame *et al.*, 1991; Hily 1991). Many studies demonstrated that suspension-feeding bivalves enhanced vertical flux of organic matter by filtering algal particles out of the water column and depositing on the seabottom (Haven and Morales-Alamo, 1966, 1972; Oviatt and Nixon, 1975; Jordan and Valiela, 1982; Doering *et al.*, 1986; Kautsky and Evans, 1987).

In the Antarctic waters, phytoplankton production is highly seasonal and restricted to a short period of time in a year. In particular, the Antarctic shallow-water (<100 m) benthic ecosystem has been considered as phytoplankton-impoverished (Grebmeier and Barry, 1991; Ahn, 1993). In spite of low water column production, the Antarctic nearshore waters are characterized by relatively high abundance of benthic communities (White, 1984) and frequently comparable to those of highly productive waters in the world. Icealgal (Burkholder and Mandelli, 1965; Andrishev, 1968) and benthic microalgal production (Palmisano *et al.*, 1985; Dayton *et al.*, 1986; Rivikin and Putt, 1987), and horizontal advection of allochtonous food particles (Littlepage and Pearse, 1962; Dayton and Oliver, 1977; Fréchette and Bourget, 1985; Barry and Dayton, 1988; Dunbar *et al.*, 1989) have been considered as other important processes providing organic material to benthic organisms in Antarctic

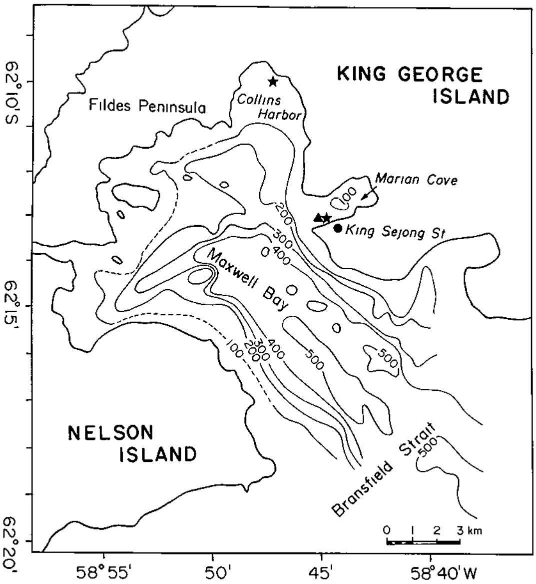

Fig. 1. Geographic location of Maxwell Bay and the sampling site. Bathymetric contours are drawn based on the information from Atlas Hidrografico Chileno Antarctico given by Instituto Hidrografico de la Armada, Chile (1982). Sea waters were sampled in Marian Cove, and *Laternula elliptica* and sediment were collected in Collins Harbor. The sampling sites were marked in asterisks. The sediment-trap deployed site is marked in triangle.

coastal waters. Quantitative studies on the relative importance of icealgal, water column and benthic algal production to benthic communities are required to understand tactics of benthic fauna dealing with variable food availability.

The Antarctic lamellibranch *Laternula elliptica* King and Broderip is widely distributed in nearshore waters around the Antarctic Continent and islands. This deep-burrowing (frequently >50 cm) species (Hardy, 1972) has a very thin shell, and grows to a shell length of approximately 100 mm in 12 to 13 years (Ralph and Maxwell, 1977). *Laternula elliptica* occurs in dense patches, on the order of tens of individuals per m^2, being one of the most conspicuous members of Antarctic infaunal assemblages (Stout and Shabica, 1970; Hardy, 1972; Zamorano *et al.*, 1986). It has also been considered as one of the key species in the Antarctic nearshore water benthic ecosystems. Ahn (1993) demonstrated that *L. elliptica* enhanced the sedimentation of organic matter. The organic carbon flux occurring through biodeposition was ca. 95 mg $C\cdot m^{-2}\cdot d^{-1}$. Ahn (1993) suggested that *L. elliptica* may nourish other benthic organisms such as *Yoldia eightsi*, which may rely directly or indirectly on the biodeposits of *L. elliptica.* Ahn (1993) contended that since fecal production is only a portion of all physiological processes relating to energy expenditure, and the water column production in this area may be not high enough to support all the physiological processes, other supplementary food sources may be necessary.

The present study was conducted as a preliminary effort to understand the feeding adaptation of *Laternula elliptica* in an environment with presumably highly variable food supply. Primary food sources for *L. elliptica* were investigated based on microscopic analysis for algal composition in the ambient seawater, trap sediment, *Laternula*-inhabiting sediment and gut content during a 16-day period of an austral summer.

MATERIALS AND METHODS

Sampling

Seawater was collected in a 125 ml polyethylene bottle from the pier in King Sejong Station in Marian Cove. Marian Cove is located within Maxwell Bay (Fig. 1). Maximum water depth in the cove is ca. 100 m. Surface water freezes in winter and melts in summer, but a variable cover of drifting icebergs occurs during most of the year. The sampling site is close to land and subject to melt-water inflow during summer from surrounding icefield, resulting in a substrate consisting of terrigenous coarse sediment (Ahn, 1991). Hydrographic features of the Maxwell Bay during summer have been described by Chang *et al.* (1990). Sampled seawater was immediately preserved with formalin (final concentration 5%) for later analysis. Sampling was conducted every 12 hours from February 1 through 16, 1993. During the period of February 6 through 16, sediment traps were deployed at 20 m water depth of Marian Cove. Traps were suspended 5 m off the bottom.

Laternula elliptica and sediment were collected in early February 1993 from 25-30 m water depth in Collins Harbor (62°13′ S, 58°45′ W). Collins Harbor is a sheltered bay with an exposed beach during summer. The sampling site is close to land and subject to fresh water inflow during summer time. In a preliminary investigation, high occurrence of *L. elliptica* was observed in this area; divers were able to collect 40 to 50 specimens in each 30-min diving. Therefore, Collins Harbor was chosen as a representative habitat of *L. elliptica*. *Laternula elliptica* were carefully hand-collected by the divers. Sediment samples were sampled to a depth of 30 cm using 28 cm^2 hand-held PVC corers by the divers. The sampled animals were transported immediately to the laboratory and dissected to collect gut content.

Microscopic Analysis of Cell Composition and Density

Membrane filter mount technique along with water-soluble embedding medium (HPMA, 2-hydroxyprophyl methacrylate) (Crumpton, 1987) was used to get quantitative information on cell composition, abundance and distribution. Subsamples of 50 to 100 ml was filtered on membrane filters, and the HPMA slides were prepared for cell counting. At least 10 fields or 300 cells were enumerated using a Zeiss Axiophot microscope with combination of light and epifluorescence microscopy (x400). A scanning electron microscope (Philips 515) was used to identify the species whose identification were not possible under the light microscope. Phytoplankton were filtered, dehydrated and critical point-dried according to the standard method by Dykstra (1992). Whole mounts coated with gold were used for the scanning electron microscopy. The number of phytoplankton cells per liter of sea water was obtained by counting numbers of cells per unit area, corrected for total area and volume used, calculated as in Kang and Fryxell (1992) and Kang *et al.* (1993) from raw microscope counts. Cell sizes and areas of dominant phytoplankton species were measured for subsequent biovolume and carbon biomass estimates. Carbon biomass was estimated from cell biovolume with the modified Strathmann equation (eq. 7 in Smayda 1978).

RESULTS

Epiphytic and epilithic diatoms comprised the majority of microalgal populations in surface water, trap and bottom sediments, and gut content of *Laternula elliptica*. Planktonic centric diatom,

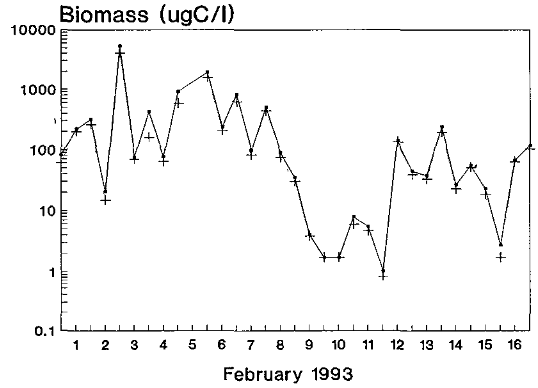

Fig. 2. Short-term variation of microalgal density in the nearshore surface water in Marian Cove. Solid line represents total diatom cell density and dotted line *Synedra* spp. Seawater was collected every 12 hours, and algal composition and density were analyzed microscopically.

Table 1. The most common diatom species in the nearshore surface waters in Marian Cove from February 1 through 16 in the year of 1993. Seawater was sampled every 12 hours to collect data for algal composition. Values are the means of the data pooled (RA, relative abundance; CA, cumulative abundance; +, < 0.1%)

Species	%RA	%CA
Synedra spp.	83	83
Licmophora spp.	14	97
Navicula spp.	2	99
Pseudogomphonema kamtschaticum	0.6	99.6
Achnanthes brevipes var. *angustata*	0.3	99.9
Cocconeis spp.	+	
Thalassiosira antarctica	+	
Cylindrotheca closterium	+	

Thalassiosira antarctica accounted for only <5% of total microalgal biomass. During the 16-day period, diatom density fluctuated considerably from 1 $\mu g \cdot C \cdot l^{-1}$ up to 5 $mg \cdot C \cdot l^{-1}$ in the nearshore surface water (Fig. 2). *Synedra* spp. (62-100% of total biomass) predominated microalgal populations throughout the 16-day period (Table 1 and Fig. 2). *Licmophora* spp. were the next common, and *Synedra* spp. and *Licmophora* spp. both together constituted 97% of total diatom biomass. *Licmophora* spp. and *Synedra* spp. also predominated in the trap sediment (Table 2).

In the surface sediment within *Laternula ellipti-*

Table 2. The most common diatom species in the sediment collected in the traps which were deployed for 10 days (Feb. 6 to 16, 1993) at 5 m off the bottom at 20 m depth in Marian Cove near King Sejong Station (RA, relative abundance; CA, cumulative abundance)

Species	%RA	%CA
Licmophora spp.	51	51
Synedra kerguelensis	11	62
Fragilaria sp.	8	70
Pseudogomphonema kamtschaticum	8	78
Navicula spp.	5	83
Corethron criophilum	5	88
Pleurosigma spp.	3	91
Achnanthes brevipes var. *angustata*	3	94
Thalassiosira antarctica	3	97
Coscinodiscus sp.	3	100
Charcotia actiochilus	+	
Cylindrotheca closterium	+	
Cocconeis spp.	+	
Pinnularia quatratareoides	+	
Trachyneis aspera	+	
Biddulphia anthropomorpha	+	
Amphora ovalis	+	
Triceratium sp.	+	
Fragilariopsis kerguelensis	+	

Table 3. The most common diatoms in the surface sediment at 30 m depth in Collins Harbor (RA, relative abundance; CA, cumulative abundance (based on cell volume))

Species	%RA	%CA
Biddulphia spp.	46	46
Cocconeis spp.	19	65
Trachyneis aspera	14	79
Pinnularia quatratareoides	5	84
Synedra kerguelensis	3	87
Triceratium sp.	3	90
Amphora ovalis	2	92
Licmophora spp.	2	94
Pleurosigma spp.	1	95
Charcotia actiochilus	1	96
Thalassiosira antarctica	1	97
Pseudogomphonema kamtschaticum	1	98
Achnanthes brevipes var. *angustata*	1	99
Fragilariopsis kerguelensis	+	
Fragilaria sp.	+	
Navicula spp.	+	
Melosira sol	+	
Coscinodiscus sp.	+	

ca habitats, *Biddulphia* spp., *Cocconeis* spp., *Trachyneis aspera* were the most dominant (Table 3).

Table 4. Microalgal composition in the gut content of *Laternula elliptica* sampled from 25-30 m depth in Collins Harbor

Species	Relative abundance (%)
Cocconeis spp.	30.0
Licmophora spp.	18.0
Trachyneis aspera	8.0
Coscinodiscus spp.	8.0
Corethron criophilum	6.0
Pseudogomphonema kamtschaticum	4.0
Thalassiosira antarctica	4.0
Melosira sol	4.0
Pinnularia quadratareoides	4.0
Nitzschia sp.	4.0
Biddulphia sp.	2.0
Pinnularia sp.	2.0
Triceratium sp.	2.0
Pleurosigma sp.	2.0
Navicula sp.	2.0

Synedra spp. and *Licmophora* spp., the most dominant species in the water column, all together comprised only 5% of the microalgal populations in the surface sediment. In the gut content of *L. elliptica* were *Cocconeis* spp. found as the most common. *Licmophora* spp., *Trachyneis aspera* and *Coscinodiscus* spp. were also common (Table 4).

DISCUSSION

Benthic diatoms predominated in water column, bottom sediment and gut content of *Laternula elliptica*. Species composition, however, varied considerably among samples. In the nearshore surface water did *Synedra* spp. predominate. In the trap sediment collected at a depth of 15 m, the proportion of *Synedra* spp. greatly decreased and instead *Licmophora* spp. were the most abundant. Ahn *et al.* (in press), however, reported that *Synedra* spp. were the most abundant throughout the depth range of 0-30 m. It appears that *Synedra* spp. are more buoyant than *Licmophora* spp., and thereby not much of them were settled in the traps. In bottom sediment at 30 m depth, diatom composition differed considerably from those of surface water and trap sediment. These differences may be due to the differences in substrate for diatoms and in part due to the differences in depth. In the gut content, *Cocconeis* spp., *Licmophora* spp. and *Trachyneis* sp. were abundant. Thus the dominant diatom species in water column and bottom sediment were also found as major gut content of *L. elliptica*. The suspension-feeding *L. elliptica* may rely on benthic diatoms while phytoplankton production is low, and the high biomass may occur due to a tight coupling of benthic primary production and a rapid and efficient utilization of organic matter by *L. elliptica*. These algal species were apparently ingested by *L. elliptica*, although it is still unknown whether they were actually absorbed or not.

Although there are only a few phytobenthic studies in the Antarctic nearshore waters, the results of these studies imply that benthic microalgae may be important primary producers during a certain period of time in a year. Dayton *et al.* (1986) measured relatively high rates of benthic primary production in McMurdo Sound, and concluded that benthic invertebrate production was more closely related to the benthic primary production than the water column production. Gilbert (1991) showed that benthic primary production clearly played an important part in seasonal production cycle in Signy island, and suggested that the benthic microalgae may assist in seeding the water column bloom through wind- and wave-induced resuspension.

On the other hand, Ahn *et al.* (in press) observed that *Synedra* spp. attached on a red benthic alga, *Bangia* sp. in intertidal zone of this area. Other dominant diatom species including *Licmophora* spp., on the other hand, were found to attach to a variety of macroalgae growing in shallow subtidal zones, such as a brown algae, *Desmarestia* spp. Thus, *Synedra* spp. appear to be originated from benthic substrates at very shallow depths compared to *Licmophora* spp. Trap studies showed that the majority of microalgal cells sedimented in the traps were benthic diatoms originated from benthic substrates, not from the overlying water. These benthic diatoms appear to be detached from a variety of benthic substrates by wind-generated waves.

In conclusion, benthic diatoms may be the most important food source for the Antarctic shallow-water benthic infauna at least during a certain period of austral summer months in phytoplankton-impoverished nearshore waters. Seasonal and annual variation of the relative importance of benthic diatoms as primary producers has to be resolved.

ACKNOWLEDGEMENTS

We acknowledge the 6th Korean Antarctic Summer Research Team for their emotional and technical support. This work was supported by Ministry of Science and Technology in Korea.

REFERENCES

Ahn, I.-Y., H. Chung, J.-S. Kang and S.-H. Kang. 1994. Preliminary studies on the ecology of neritic marine diatoms in Maxwell Bay, King George Island, Antarctica. *Korean J. Phycol.* **9:** [in press].

Ahn, I.-Y. and Y.-C. Kang. 1991. Preliminary study on the macrobenthic community of Maxwell Bay, South Shetland Islands, Antarctica. *Korean J. Polar Res.* **2:** 61-71.

Ahn, I.-Y. 1993. Enhanced particle flux through the biodeposition by the Antarctic suspension-feeding bivalve *Laternula elliptica* in Marian Cove, King George Island. *J. Exp. Mar. Biol. Ecol.* **171:** 75-90.

Andriashev, A.P. 1968. The problem of the life community associated with the Antarctic fast ice. *In*, Symposium on Antarctic Oceanography. Santiago, Chile, B-16, September 1966. Cambridge, Scott Polar Research Institute. pp. 147-155.

Barry, J.P. and P.K. Dayton. 1988. Current Patterns in McMurdo Sound, Antarctica and their relationship to local biotic communities. *Polar Biol.* **8:** 367-376.

Burkholder, P.R. and E.F. Mandelli. 1965. Productivity of microalgae in Antarctic sea ice. *Science* **149:** 872-874.

Chang, K.I., H.K. Jun, G.T. Park and Y.S. Eo. 1990. Oceanographic conditions of Maxwell Bay, King George Island, Antarctica (Austral summer 1989). *Korean J. Polar Res.* **1:** 27-46.

Crumpton, W.G. 1987. A simple and reliable method for making permanent mounts of phytoplankton for light and fluorescence microscopy. *Limnol. Oceanogr.* **32:** 1154-1159.

Dame, R., N. Dankers, T. Prins, H. Jongsma and A. Smaal. 1991. The influence of mussel bed on nutrients in the western Wadden Sea and eastern Scheldt estuaries. *Estuaries* **14:** 130-138.

Dayton, P.K. and J.S. Oliver. 1977. Antarctic soft-bottom benthos in oligotrophic and eutrophic environments. *Science* **197:** 55-58.

Dayton, P.K., D. Watson, A. Palmisano, J.P. Barry, J.S. Oliver and D. Rivera. 1986. Distribution patterns of benthic microalgal standing stock at McMurdo Sound, Antarctica. *Polar Biol.* **6:** 207-213.

Doering, P.H., C.A. Oviatt and J.R. Kelly. 1986. The effects of the filter-feeding clam *Mercenaria mercenaria* on carbon cycling in experimental marine mesocosms. *J. Mar. Res.* **44:** 839-861.

Dunbar, R.B., A.R. Leventer and W.L. Stockton. 1989. Biogenic sedimentation in McMurdo Sound, Antarctica. *Mar. Geol.* **85:** 155-179.

Dykstra, M.J. 1992. Biological Electron Microscopy. Theory, Techniques, and Trouble Shooting. Plenum Press, New York and London. 360 pp.

Flint, R.W. and D. Kamykowski. 1984. Benthic nutrient regeneration in South Texas coastal waters. *Estuar. Coast. Shelf Sci.* **18:** 221-230.

Fréchette, M. and E. Bourget. 1985. Energy flow between the pelagic and benthic zones: factors controlling particulate organic matter available to an intertidal mussel bed. *Can. J. Fish. Aquat. Sci.* **42:** 1158-1163.

Gilbert, N.S. 1991. Microphytobenthic seasonality in near-shore marine sediments at Signy Island, South Orkney Islands, Antarctica. *Estuar. Coast. Shelf Sci.* **33:** 89-104.

Grebmeier, J. and J. P. Barry. 1991. The influence of oceanographic processes on pelagic-benthic coupling in polar regions: A benthic perspective. *J. Mar. Sys.* **2:** 495-518.

Hardy, P. 1972. Biomass estimates from some shallow-water infaunal communities at Signy Island, South Orkney Island. *Br. Antarct. Surv. Bull.* **31:** 93-106.

Hargrave, B.T. 1973. Coupling carbon flow through some pelagic and benthic communities. *J. Fish. Res. Board Can.* **30:** 1317-1326.

Haven, D.S. and R. Morales-Alamo. 1966. Aspects of biodeposition by oysters and other invertebrate filter feeders. *Limnol. Oceanogr.* **11:** 487-498.

Haven, D.S. and R. Morales-Alamo. 1972. Biodeposition as a factor in sedimentation of fine suspended solids in estuaries. *Geol. Soc. Amer. Mem.* **133:** 121-130.

Hily, C. 1991. Is the activity of benthic suspension feeders a factor controlling water quality in the Bay of Brest? *Mar. Ecol. Prog. Ser.* **69:** 179-188.

Jordan, T.E. and I. Valiela. 1982. A nitrogen budget of the ribbed mussel, *Geukensia demissa*, and its significance in nitrogen flow in a New England salt marsh. *Limnol. Oceanogr.* **27:** 75-90.

Kautsky, N. and S. Evans. 1987. Role of biodeposition by *Mytilus edulis* in the circulation of matter and nutrients in a Baltic coastal ecosystem. *Mar. Ecol. Prog. Ser.* **38:** 201-212.

Kang, S.-H. and G.A. Fryxell. 1993. Phytoplankton in the Weddell Sea, Antarctica: composition, abundance and distribution in the water column assemblages of the marginal ice-edge zone during austral autumn. *Mar. Biol.* **116:** 335-348.

Kang, S.-H., G.A. Fryxell and D.L. Roelke. 1993. *Fragilariopsis cylindrus* compared with other species of the diatom family Bacillariaceae in Antarctic marginal ice-edge zones. *Nova Hedwigia* **106:** 335-352.

Littlepage, L. and J. Pearse. 1962. Biological and oceanographic observations under an Antarctic ice shelf. *Science* **137:** 679-680.

Loo, Lars-Ove and R. Rosenberg. 1989. Bivalve suspension-feeding dynamics and benthic-pelagic coupling in an eutrophicated marine bay. *J. Exp. Mar. Biol. Ecol.* **130:** 253-276.

Murphy, R.C. and J.N. Kremer. 1985. Bivalve contribution to benthic metabolism in a California lagoon. *Estuaries* **8:** 330-341.

Nixon, S.W., C.A. Oviatt and S.S. Hale. 1975. Nitrogen regeneration and the metabolism of coastal marine bottom communities. *In*, Anderson, J. M. and A. Macfadyen (eds.). The Role of Terrestrial and Aquatic Organisms in Decomposition Processes. Blackwell, Oxford. pp. 269-283.

Oviatt, C.A. and S.W. Nixon. 1975. Sediment resuspension and deposition in Narragansett Bay. *Estuar. Coast. Mar. Sci.* **3:** 201-217.

Palmisano, A.C., J.B. SooHoo, D.C. White, G.A. Smith and G.R. Stanton. 1985. Shade adapted benthic diatoms beneath Antarctic sea ice. *J. Phycol.* **21:** 664-667.

Ralph, R. and J.G.H. Maxwell. 1977. Growth of two Antarctic lamellibranchs: *Adamussium colbecki* and *Laternula elliptica*. *Mar. Biol.* **42:** 171-175.

Rivikin, R.B. and M. Putt. 1987. Photosynthesis and cell division by Antarctic microalgae: comparison of benthic, planktonic and ice algae. *J. Phycol.* **23:** 223-229.

Smayda, T.J. 1978. From phytoplankton to biomass. *In*, Sournia, A. (ed.). Phytoplankton Manual. Page Brothers (Norwich) Ltd. pp. 272-279.

Sornin, J.M., Y. Collos, D. Delmas, M. Feuillet-Girard, D. Gouleau. 1990. Nitrogenous nutrient transfers in oyster ponds: Role of sediment in deferred primary production. *Mar. Ecol. Prog. Ser.* **68:** 15-22.

Stout, W.E. and S.V. Shabica. 1970. Marine ecological studies at Palmer Station and vicinity. *Antarct. J. U. S.* **5:** 134-135.

White, M.G. 1984. Marine benthos. *In*, Laws, R.M. (ed). Antarctic Ecology, Vol. 2. pp. 421-461.

Zamorano, J.H., W.E. Durate and C.A. Moreno. 1986. Predation upon *Laternula elliptica* (Bivalvia, Anatinidae): A field manipulation in South Bay, Antarctica. *Polar Biol.* **6:** 139-143.