ECOLOGY OF THE ANTARCTIC BIVALVE *LATERNULA ELLIPTICA* (KING AND BRODERIP) IN COLLINS HARBOR, KING GEORGE ISLAND: BENTHIC ENVIRONMENT AND AN ADAPTIVE STRATEGY

In-Young AHN

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

Abstract : The Antarctic lamellibranch *Laternula elliptica* occurs commonly in shallow waters around the Antarctic Continent and islands. Physical and chemical characteristics of the bottom environment of a representative habitat were investigated to understand the successful adaptation of this species in the Antarctic nearshore waters. A high density of *L. elliptica* (average 87 ind. m^{-2}, approx. 9 kg m^{-2}) occurred at 25–30 m water depth of Collins Harbor, a sheltered bay with a wide area of exposed rocky beach during summer time. Bottom substrate was sandy mud mixed with gravel particles. Sedimentary organic carbon content was very low (0.2–0.8%) apparently due to massive land runoff during summer months. Carbon value was relatively high (1.23%) in surface flocculent ooze which consisted almost entirely of benthic diatoms and organic aggregates, indicating a tight coupling of benthic primary production and a rapid and complete utilization of organic matter by benthic animals. *L. elliptica* was not found at depths less than 5 m (pebble zone), indicating that physical instability due to ice abrasion may be a factor determining the upper limit of vertical distribution of this species. Deep-burrowing seems to be primarily a means for avoiding ice impacts. A pair of stout and highly extendable siphons appear to be a morphological feature to feed in the ice-scoured substrate while staying deep in the sediment. The present study suggests that a trade-off between increasing physical stability and decreasing food input with depth may determine both the depth range of vertical distribution and the magnitude of *Laternula elliptica* biomass.

Key words: Antarctic, *Laternula elliptica*, ice impacts, distribution, density, sediment

1. Introduction

The Antarctic marine benthic ecosystem is characterized by a stable and uniform physical environment. Temperature and salinity vary little all year round. Benthic communities show relatively high diversity and biomass comparable to highly productive areas in the world (WHITE, 1984). In the Antarctic nearshore waters, however, ice-abrasion is a prevailing physical factor affecting the spatial distribution of benthic communities (DAYTON et al., 1970; GRUZOV, 1977; RICHARDSON and HEDGPETH, 1977). Scouring by grounded icebergs (SHABICA, 1972; GRUZOV, 1977; RICHARDSON and HEDGPETH, 1977) and anchor ice (bottom-forming ice) formation (DAYTON et al., 1969; SHABICA, 1972) are very common in the depth range less than 30 m.

The Antarctic lamellibranch *Laternula elliptica* (King and Broderip) is widely distributed in nearshore waters around the Antarctic continent and islands. It is also one of the most common macrofossils found on emerged beaches around Antarctica (BERKMAN, 1991). There is little information on the geological history of *L. elliptica*, but it is known that the genus *Laternula* dates from the late Cretaceous. Today, the species of the genus *Laternula* are distributed over a wide area of tropical and subtropical waters from the Red Sea to Australia, and to the Far East, Japan (DELL, 1972). *L. elliptica* is the only representative of the genus *Laternula* in the Antarctic waters. .

Laternula elliptica seems to be a predominantly shallow-water species, although due to the depth limitation in SCUBA diving only shallow-water habitats have been investigated. Shells have been collected in depths from 1 to 500 m, but almost all live-collected specimens have been taken from depths less than 100 m and probably commonest shallower than 20 m (DELL, 1990). It occurs in dense patches in sheltered bays, on the order of tens of individuals per m^2, being one of the most conspicuous members of Antarctic infaunal assemblages in nearshore waters (<50 m) (STOUT and SHABICA, 1970; HARDY, 1972; ZAMORANO et al., 1986; AHN, 1993).

Marian Cove, Collins Harbor and the vicinity in Maxwell Bay, King George Island have been investigated to search *Laternula elliptica* during the 1991/1992 and the 1992/1993 austral summer months. Hydrographic features of the bay during summer have been described by CHANG et al. (1990). In Marian Cove, the density of *L. elliptica* ranged from 36 to 88 ind. m^{-2} with the mean of 65 ind. m^{-2} (SD = 15, $n=14$) at 15 ± 2 m water depth in early January of 1992 (AHN, 1993). AHN (1993) demonstrated that *L. elliptica* enhanced the organic carbon flux from the water column to the sea bed through biodeposition. AHN (1993) also suggested that water column primary production in this area may be not sufficient to support all energy expenditure of this bivalve species, and other supplementary food sources may be necessary. From an ecological viewpoint, the mechanisms by which this bivalve species has adapted to the ice-scoured and phytoplankton-impoverished environment are of great interest.

In a preliminary investigation, high occurrence of *Laternula elliptica* was observed in Collins Harbor in the 1992/1993 season. Since divers were able to collect a large number (40 to 50) of *L. elliptica* in each 30-min diving session, more than ever collected for the same effort, Collins Harbor was chosen as a representative habitat of *L. elliptica*. In early February 1993, the density of *L. elliptica* was estimated in Collins Harbor, and physico-chemical characteristics of the bottom environment were investigated to understand the successful adaptation of this species in the Antarctic nearshore environment.

2. Materials and Methods

Collins Harbor (62°10′S, 58°47′W) is a sheltered bay with a few hundred m-wide and a half km-long rocky beach which is exposed during summer time (Fig. 1). A variable coverage of drifting ice was observed during the period of investigation. The sampling site is close to land and subject to freshwater inflow during summer time. No *Laternula elliptica* was found in the shallow subtidal zone (<5 m) which consisted mostly of pebbles and cobbles. Water depth gradually increased down to 10 m and then sharply
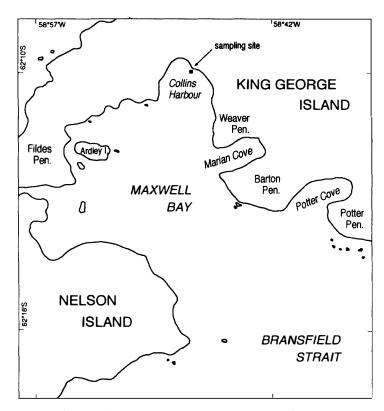
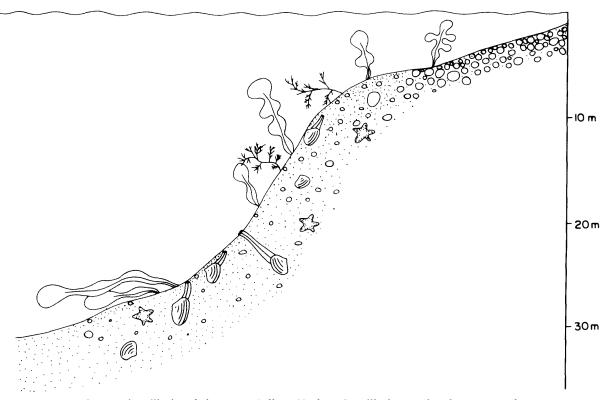*Fig. 1.   Geographic location of Collins Harbor and the sampling site.*

Fig. 2.   Laternula elliptica habitat in Collins Harbor. L. elliptica and sediment samples were taken from 25–30 m depth by SCUBA divers in early February 1993.

dropped to 25–30 m depth (Fig. 2). *L. elliptica* began to appear at depths of 6–7 m on the gentle slope. On the slope a fair amount of rock fragments were embedded in mud-sand matrix, forming a semi-consolidated substrate. At the depths of 25–30 m, the bottom was flat, and the substrate consisted mostly of mud. Sampling *L. elliptica* on the slope in quantities was not possible within a limited time, because they buried themselves deep in the semi-consolidated sediment. The flat muddy bottom at 25–30 m depths was chosen as the site for sampling both *L. elliptica* and sediment, because many of *L. elliptica* were partially buried or completely exposed at the surface.

Biomass was estimated by counting number of siphon pairs and then multiplying the average number of siphons by the average weight of randomly sampled specimens. Twelve $0.25 \, m^2$ quadrats were randomly placed in bottom sediment and then the number of siphon pairs within each quadrat was counted by divers in early February 1993 from 25–30 m water depth in Collins Harbor. *Laternula elliptica* were hand-collected by the divers.

Sediment samples were also taken by the divers using a $28 \, cm^2$ hand-held PVC corer ($n = 6$) which sampled sediment to 30 cm depth. Sampled animals and sediment cores were immediately transported to the laboratory. Wet weight and shell length of the animals were measured. Subsamples were taken from several depths of each sediment core and dried at 60°C for later analysis of organic carbon. Organic carbon was determined using a Carlo Erba NA-1500 Analyzer after removing calcium carbonate with 8% sulfurous acid (VERARDO *et al.*, 1990). Sediment grain size was analyzed using a Ro-Tap sieve shaker for sediment particles larger than 4 phi and using Sedigraph 5000D for those smaller than 4 phi after removing organic matter by soaking in 30% H_2O_2 and by rinsing with distilled water.

3. Results

Density of *Laternula elliptica* ranged from 28 to 136 ind. m^{-2} at 25–30 m water depth with the mean value of 87 ind. m^{-2} (SD = 34, $n = 12$). Bottom substrate was sandy

Table 1.   Physico-chemical characteristics of Laternula elliptica *habitat. Sediment samples were collected by divers using a hand-held PVC corer ($28 \, cm^2$, n = 5) at 25–30 m water depth of Collins Harbor in February 16, 1993. Means (SD) are presented for the five replicate samples.*: n = 2

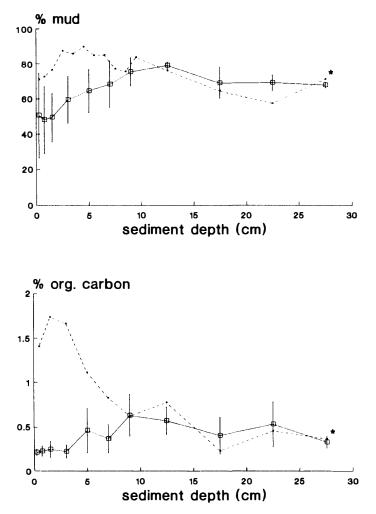| Depth(cm)	%mud	%sand	%gravel	%water	%org C	%CaCO₃
0–0.5	50.7 (24.0)	46.8 (22.6)	2.6 (3.59)	39.4 (2.28)	0.230 (0.018)	0.490 (0.091)
0.5–1	48.1 (19.0)	50.5 (18.2)	1.3 (1.97)	37.7 (2.49)	0.228 (0.059)	0.471 (0.074)
1–2	49.5 (13.8)	45.3 (14.8)	5.2 (9.04)	38.4 (5.14)	0.282 (0.056)	0.470 (0.044)
2–4	59.5 (13.4)	36.9 (12.3)	3.6 (3.46)	39.6 (8.99)	0.224 (0.074)	0.539 (0.122)
4–6	64.5 (12.3)	30.7 (9.07)	4.8 (3.77)	42.8 (11.0)	0.460 (0.250)	0.313 (0.132)
6–8	68.4 (13.2)	28.3 (11.3)	3.3 (2.27)	42.1 (7.32)	0.365 (0.159)	0.318 (0.084)
8–10	75.4 (7.95)	22.0 (5.58)	2.6 (2.97)	44.5 (6.70)	0.630 (0.236)	0.188 (0.162)
10–15	79.0 (1.92)	19.3 (1.38)	1.7 (1.81)	42.8 (3.67)	0.569 (0.153)	0.214 (0.129)
15–20	69.0 (8.81)	26.6 (6.62)	4.5 (2.78)	36.3 (2.51)	0.406 (0.210)	0.361 (0.102)
20–25	69.2 (4.48)	26.6 (4.59)	4.1 (2.16)	38.3 (3.65)	0.531 (0.252)	0.379 (0.060)
25–30*	68.0 (1.64)	28.2 (4.01)	3.8 (2.37)	37.3 (5.16)	0.328 (0.068)	0.537 (0.016)

% mud

Fig. 3. *Vertical variation of organic carbon and mud contents in the sediment cores taken in Collins Harbor. Solid lines represent the mean and the standard deviations of 5 out of the 6 core samples (*: n = 2). Dotted lines represent the values of the 6th core which shows high organic carbon and mud contents in the top 10 cm layer.*
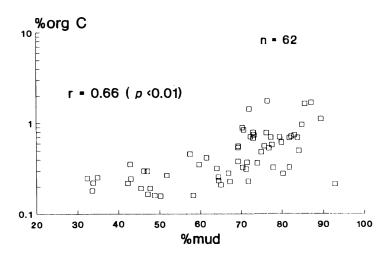
%org C

n = 62

r = 0.66 (p <0.01)

Fig. 4. *Positive correlation between sediment organic carbon and mud contents. r: product-moment correlation coefficient (SOKAL and ROHLF, 1981).*
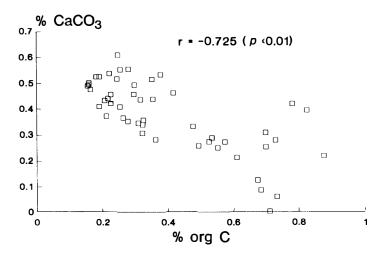
Fig. 5. Negative correlation between sediment organic carbon and calcium carbonate contents. r:
product-moment correlation coefficient (SOKAL and ROHLF, 1981).

mud mixed with gravel particles (Table 1). Organic carbon content of the bottom
sediment was very low, ranging from 0.2% to 0.8%. There was an extreme lateral
variability, but only in the top 10 cm layer, and below this layer, the carbon value
follows the general pattern (Fig. 3). The carbon values positively correlated with the
mud content (Fig. 4). Calcium carbonate contents were generally less than 1%, and
showed a negative correlation with organic carbon contents (Fig. 5).

4. Discussion

Although the actual biomass was apparently underestimated with the counting
method, the average density value of 87 ind. m^{-2} was higher than the most of the values
reported in other Antarctic nearshore waters (Table 2). Collins Harbor, a sheltered bay
with exposed beaches during summer, is apparently a favorable habitat for *Laternula
elliptica*.

The sedimentary organic carbon content (0.2–0.8%) was very low for nearshore
sediment, but falls well within the ranges reported in other Antarctic nearshore sediments
(WARNKE et al., 1973; MILLS and HESSLER, 1974; RICHARDSON and HEDGPETH, 1977;
SCHNACK, 1985; AHN, 1993). The low carbon value seems to be primarily related to
massive land runoff during the summer months. The extreme horizontal variability in
organic carbon content is possibly due to bottom topography. It has been reported that
grounded icebergs in shallow waters destroy macrobenthic fauna, and a depression is
left by the mechanical action of icebergs (RICHARDSON and HEDGPETH, 1977). The higher
organic carbon value in the upper layer of one sediment core is apparently due to the
accumulation of organic-rich fine grains in shallow depressions. The negative correlation
between organic carbon and calcium carbonate seems to be related to changes in the
supply rate of calcium carbonate. STEIN (1991) reported that high supply rates of detrital
carbonates resulted in low organic carbon contents because of dilution, and low supply
rates resulted in a relative enrichment of organic carbon.

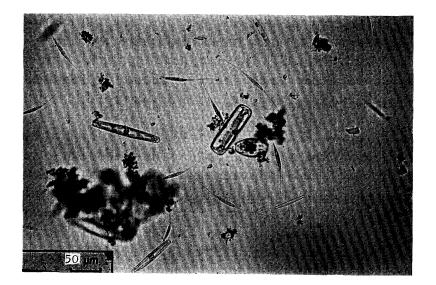Organic carbon values, however, were relatively high (1.23%) in the surface film

Fig. 6. *Surface flocculent matter which consists entirely of benthic diatoms and organic aggregates in the* Laternula elliptica *habitat.*

which was sampled by a diver using a syringe. Microscopic observation showed that the surface film consisted almost entirely of benthic diatoms and organic aggregates (Fig. 6). The low organic carbon values in the sediment cores in spite of the high value on the surface film imply a tight coupling of benthic primary production and a rapid and efficient utilization of organic matter on the surface by benthic animals (MILLS and HESSLER, 1974; RICHARDSON and HEDGPETH, 1977).

The fact that no *Laternula elliptica* were found in depths less than 5 m in the pebble-cobble substrate implied that both the degree of ice impacts and the substrate type may affect their spatial pattern. *L. elliptica* is known to burrow deep (frequently > 50 cm) into sediment (HARDY, 1972). In temperate coastal waters, however, the related species *Laternula anatina* (< 5 cm in shell length) was collected easily by dredging from the depth range of 16–24 m in muddy sand (JE *et al.*, 1991), implying that its burrowing depth may be not as deep as in the case of *L. elliptica* ($\approx$ 11 cm). The posterior gape, through which huge siphons protrude, is wider in proportion to the shell length in *L. elliptica* than in *L. anatina* (pers. obser.), indicating that siphons of the former are thicker than those of the later.

Thus, deep-burrowing seems to be a means to avoid ice impacts. Grounded icebergs have been found to crush or unbury *Laternula elliptica* (SHABICA, 1972) and other benthic infaunal organisms (GRUZOV, 1977; RICHARDSON and HEDGPETH, 1977). Anchor ice has been reported to lift away other benthic organisms (DAYTON *et al.*, 1969; SHABICA, 1972). A pair of stout and highly extendable siphons appear to be a morphological feature to adapt in environments mechanically affected by ice. With only the siphonal opening exposed at the surface, it feeds while the rest of the body is staying deep in the sediment to avoid ice impacts.

Deep-burrowing is also likely to be a way to avoid predation. Once unburied at the surface by grounded icebergs etc., they are soon attacked by predators such as starfishes (DAYTON *et al.*, 1974; ZAMORANO *et al.*, 1986). These epifaunal predators are

generally rare in the severely ice-affected sub-littoral zone, but increase in number in deeper water as substrate is physically stabilized (Dayton et al., 1970; Gruzov, 1977; Richardson and Hedgpeth, 1977). However, many L. elliptica were exposed or only partially buried in the deeper waters (20–30 m) despite the increased risk of being predated, implying that deep-burrowing is primarily a mean to defend themselves against ice impacts.

Despite the disruptive effects of ice, there seems to be some advantages in living at relatively unstable shallow sublittoral bottoms; more food. In a companion study (Ahn et al., 1993) conducted during the same period, epiphytic and epilithic diatoms were the most dominant microalgal species in both the ambient seawater and the gut content of Laternula elliptica. These benthic diatoms were found to attach on the surface sediment and macroalgae which occur in a variety of densities in L. elliptica habitats. Density of these diatoms was several times higher at shallow subtidal water (< 50 m) near macroalgal beds than in the bay mouth (> 500 m). High occurrences of these benthic diatoms in the nearshore water (up to $5 \, \mathrm{mgC} \, l^{-1}$) frequently coincided with strong wind breakouts. Benthic microalgae appear to be resuspended by wind-generated waves so that L. elliptica can filter these particles out of the water column. Although there are only a few microphytobenthic studies in the Antarctic nearshore waters, the results of these studies suggested that benthic microalgae may be important primary producers during certain periods of the 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 (1991a) 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. Gilbert (1991b) also demonstrated that benthic microalgae were highly productive in the nearshore sediments before and after phytoplankton blooms during summer time.

The suspension-feeding Laternula 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. If benthic diatoms constitute an important food item for a certain periods of the year, L. elliptica should remain at the shallow depths, because benthic diatoms need illumination, implying that the lower limit of vertical distribution of L. elliptica may be determined by food availability. On the other hand, as explained earlier, if the upper limit of vertical distribution may be determined by the mechanical impacts of ice, the vertical distribution of L. elliptica should be restricted to a narrow depth range, which seems to be a real situation.

Although the observation has been supported only by a few quantitative studies, high biomass of Laternula elliptica seems to occur in the shallow sub-littoral zone (< 30 m) (Table 2). Within the depth range of 5–30 m, the biomass tends to increase with increasing water depth (Fig. 7). Food input generally decreases with increasing water depth, but total amount of food ingested could be larger in deeper water by virtue of increased feeding time in more stable substrates. Thus, the present study suggests that a trade-off between two controlling factors, physical stability of the bottom substrate

Table 2. Densities of Laternula elliptica *in several nearshore sites.*

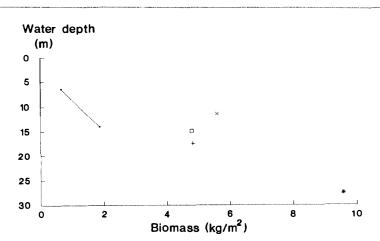| Location	Depth(m)	m^{-2}	$kg\,m^{-2}$	Substrate	References
Antarctic Peninsula (72°S, 68°W)	9–14	75		semi-consolidated	STOUT and SHABICA (1970)
Signy Island (60°S, 45°W)	6–7	9		sand/silt/gravel	HARDY (1972)
	13–15	26	1.5	sand/silt/gravel	
South Bay, Doumer Is. (64°52'S, 6°36'W)	15–20	65	2.6	muddy sand	ZAMORANO *et al.* (1986)
Marian Cove (62°13'S, 58°45'W)	13–17	65	4.8	mud/sand/gravel	AHN (1993)
Collins Harbor (62°10'S, 58°47'W)	25–30	86	9.0	mud/sand/gravel	This study

Fig. 7. Laternula elliptica *biomass estimates from different water depths at several localities. Refer to Table 2 for the details of data.*
—▲— *HARDY (1972),* + *ZAMORANO et al. (1986),* □ *AHN (1993),* × *STOUT and SHABICA (1970),* * *This study.*

and food availability may determine both the depth range of vertical distribution and magnitude of the biomass of *L. elliptica.*

Acknowledgments

References

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.
AHN, 1.-Y., KANG, J.-S. and KANG, S.-H. (1993): Primary food sources for shallow-water benthic fauna in Marian Cove, King George Island during an austral summer. Korean J. Polar Res., **4**(2), 67–72.

BERKMAN, P. A. (1991): Holocene meltwater variations recorded in Antarctic coastal marine benthic assemblages. International Conference on the Role of the Polar Regions in Global Changes, ed. by G. WELLER et al. Fairbanks, Univ. Alaska, 440–449.

CHANG, K. I., JUN, H. K., PARK, G. T. and EO, Y. S. (1990): Oceanographic conditions of Maxwell Bay, King George Island, Antarctica (austral summer 1989). Korean J. Polar Res., 1(1), 27–46.

DAYTON, P. K., ROBILLIARD, G. A. and DEVRIES, A. L. (1969): Anchor ice formation in McMurdo Sound, Antarctica, and its biological effects. Science, 163, 273–274.

DAYTON, P. K., ROBILLIARD, G. A. and PAINE, R. T. (1970): Benthic faunal zonation as a result of anchor ice at McMurdo Sound, Antarctica. Antarctic Ecology, Vol. 1, ed. by M. W. HOLDGATE. London, Academic Press, 244–258.

DAYTON, P. K., ROBILLIARD, G. A., PAINE, R. T. and DAYTON, L. (1974): Biological accommodation in the benthic community at McMurdo Sound, Antarctica. Ecol. Monogr., 44, 105–128.

DAYTON, P. K., WATSON, S., PALMISANO, A., BARRY, J. P., OLIVER, J. S. and RIVERA, D. (1986): Distribution patterns of the benthic microalgal standing stock at McMurdo Sound, Antarctica. Polar Biol., 6, 207–213.

DELL, R. K. (1972): Antarctic Benthos. Adv. Mar. Biol., 10, 1–216.

DELL, R. K. (1990): Antarctic Mollusca—with special reference to the fauna of the Ross Sea. R. Soc. N. Z., Bull., 27, 311 p.

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

GILBERT, N. S. (1991b): Primary production by benthic microalgae in nearshore marine sediments of Signy Island, Antarctica. Polar Biol., 11, 339–346.

GRUZOV, E. N. (1977): Seasonal alterations in coastal communities in the Davis Sea. Adaptations within Antarctic Ecosystems, ed. by G. A. LLANO. Houston, Gulf Publ., 263–278.

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

JE, J.-G., PARK, H.-S., LIM, H.-S. and LEE, J.-S. (1991): Distribution pattern of benthic invertebrates dredged in the coastal waters of Chungchongnamdo, Korea (Yellow Sea). Yellow Sea Res., 4, 103–119.

MILLS, E. and HESSLER, R. R. (1974): Antarctic benthic communities: Hudson '70 expedition. Antarct. J. U. S., 9, 312–316.

RICHARDSON, M. D. and HEDGPETH, J. W. (1977): Antarctic soft-bottom, macrobenthic community adaptations to a cold, stable, highly productive, glacially affected environment. Adaptations within Antarctic Ecosystems, ed. by G. A. LLANO. Houston, Gulf Publ., 181–196

SCHNACK, S. B. (1985): A note on the sedimentation of particulate matter in Antarctic waters during summer. Meeresforschung, 30, 306–315.

SHABICA, S. V. (1972): Tidal zone ecology at Palmer Station. Antarct. J. U. S., 7(5), 185–186.

SOKAL, R. R. and ROHLF, F. J. (1981): Biometry, 2nd ed. San Francisco, W. H. Freeman, 859 p.

STEIN, R. (1991): Accumulation of organic carbon in marine sediments. Lecture Notes in Earth Sciences Number 34, Berlin, Springer, 69 p.

STOUT, W. E. and SHABICA, S. V. (1970): Marine ecological studies at Palmer Station and vicinity. Antarct. J. U. S., 5(4), 134–135.

VERARDO, D. J., FROELICH, P. N. FROELICH and MCINTYRE, A. (1990): Determination of organic carbon and nitrogen in marine sediments using the Carlo Erba NA-1500 Analyzer. Deep-Sea Res., 37, 157–165.

WARNKE, D. A., RICHTER, J and OPPENHEIMER, C. H. (1973): Characteristics of the nearshore environment off the south coast of Anvers Island, Antarctic Peninsula. Limnol. Oceanogr., 18, 131–142.

WHITE, M. G. (1984): Marine benthos. Antarctic Ecology, Vol. 2, ed. by R. M. LAWS. London, Academic Press, 421–461.

ZAMORANO, J. H., DURATE, W. E. and MORENO, C. A. (1986): Predation upon Laternula elliptica (Bivalvia, Anatinidae): A field manipulation in South Bay, Antarctica. Polar Biol., 6, 139–143.