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Feeding of *Euphausia superba* Dana under natural conditions*)

ABSTRACT: Studies were carried out in the region of southern. Drake Passage and Bransfield Strait in February and March 1981. The relation occurring between the alimentary tract filling (*ATF*) and the quantity of chlorophyll *a* integrated within the range of 0–150 m water-layer may be described by Ivlev's equation expressing the amount of the food ration in relation to food concentration. The *ATF* value increases in large individuals and is proportional to their body weight. The daily rythm of krill feeding, expressed by *ATF*, depends on the quantities of food in the environment.

Key words: FIBEX, feeding of krill

1. Introduction

The feeding of krill is of great importance in the circulation of matter and energy flow in the Antarctic ecosystem. Krill is a phytophagous animal (Barkley 1940), filtering food and preferring waters where small-sized diatoms prevail (Kawamura 1981). Analysis of the degree of the alimentary tract filling of krill caught at various hours of the day and night indicates (Pavlov 1969, 1974) the existence of a feeding rythm associated with the dispersion of krill swarms taking food at night. The alimentary tract filling of krill was also analysed by Kalinowski and Witek (1980), the obtained results showed lower values of the *ATF*, in the daytime. Antezana, Ray and Melo (1982) report that krill fed under laboratory conditions may produce up to 80 cm-long faecal pellets during 24 hours. So, it seems that the rate of the alimentary tract filling (*ATF*) of krill may be treated as "instantaneous" food ration. The feeding rythm of krill, as suggested by

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Everson and Ward (1980), depends on the size of individuals showing a different range of vertical migrations. Physiological studies (Mężykowski and Rakusa-Suszczewski 1979) indicate the existence of a 24-hour rythm of utilization of nutritive substances by *Euphausia superba*. Observations of the feeding of krill under laboratory conditions do not confirm the 24-hour rythm of food intake (Antezana, Ray and Melo, 1982). The observations of krill in the aquarium showed that it may also feed on fresh-water *Chlorella*. *Euphausia superba* females fed during more than 3 weeks at Arctowski station laid eggs at that time and starved krill took food in the daytime (Rakusa-Suszczewski — unpublished data).

The aim of this study was to determine the relationship between the degree of the alimentary tract filling, the quantity of food in the environment, the size of krill individuals, and the 24-hour feeding rythm of krill.

2. Materials and methods

Fishering of krill was carried out using a stern trawl. A sample of 100 individuals was taken at random from the total catch of krill. They were measured according to the Standard 1 (Mauchline)[1]) with accuracy to 1 mm. The alimentary tract filling (*ATF*) was determined according to a 5-degree scale: 1° — stomach empty, stomach and hepatopancreas colourless, 2° — stomach filled with food, 3° — stomach and cephalothorax gut filled with food, 4° — faecal mass fills a part of intestine reaching up to the half of the total length of the abdomen, 5° — faecal mass reaches beyond the half of the total length of the abdomen. For the analyses 35 hauls of krill (3500) individuals were selected. Out of this number only in 30 hauls it was possible to make comparison of the *ATF* values with the quantity of chlorophyll *a*. The analyses were made at 18 stations in the vicinity of krill fisheries (Fig. 1, Table I). Chlorophyll *a* content was determined spectrophotometrically after Jeffrey and Humphrey (1975) in water sampled at the depths of 0, 10, 20, 30, 50, 75, 100 and 150 m. The obtained data on chlorophyll *a* content are given as integrated values in the column of water from 0 to 150 m and 0 to 100 m deep in mg under 1 m^2 of the sea surface. Numeration of the sampling stations is given in conformity with the common system used in all the studies carried out on board of the r/v "Profesor Siedlecki" in the region "A" covered by the research programme BIOMASS-FIBEX (Rakusa-Suszczewski 1982).

Analyses of krill samples were made jointly by N. Wolnomiejski, H. Czykieta, R. Stępnik and H. Jackowska. Analyses of chlorophyll *a* were made by M. Lipski. Statistical calculations were made at the "Data Workshop" in Hamburg with the help of Mr. T. Schwinghammer to whom I wish to express my gratitude.

[1]) Mauchline J. — Measurement of body length of *Euphausia superba* Dana. BIOMASS, Handbook No. 4, SCAR/SCOR/IABO/ACMRR.

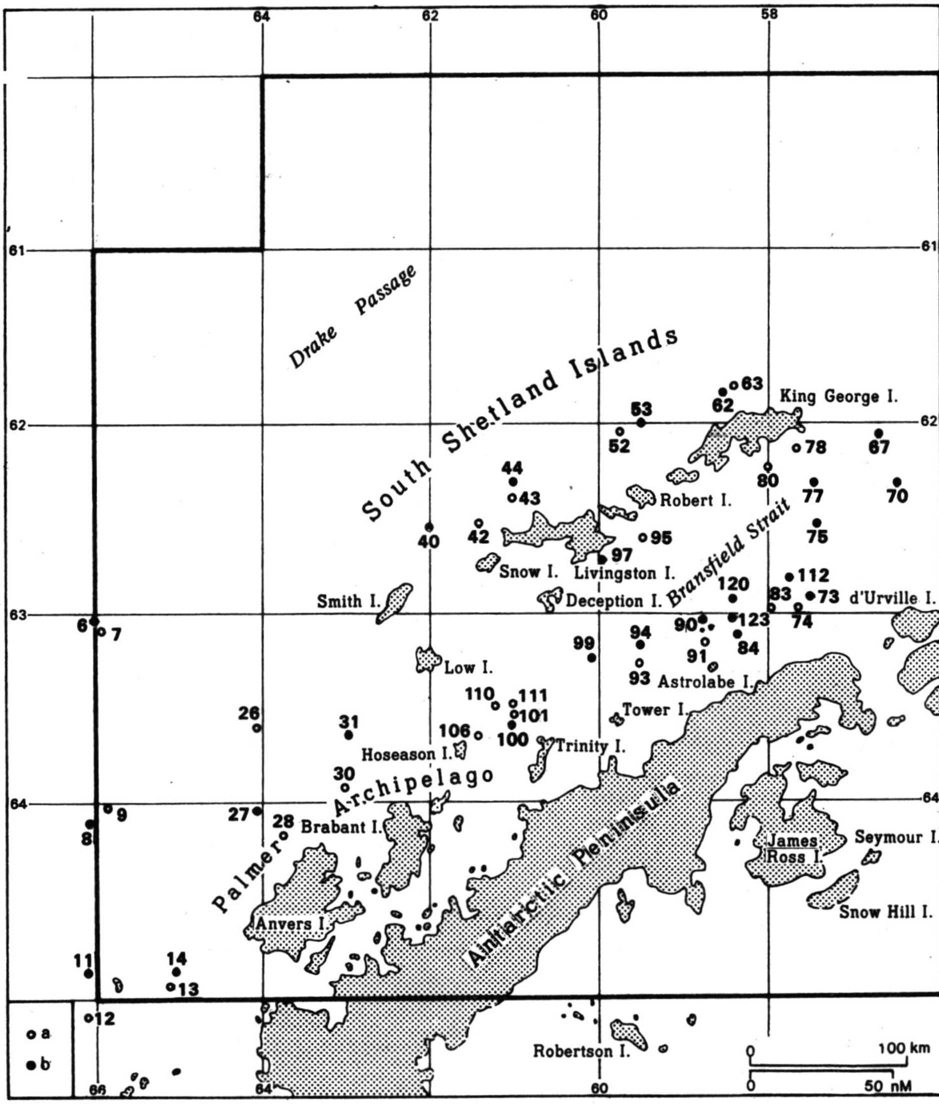

Fig. 1. Research region, numbers show krill fisheries (a) and sampling stations for the determination of chlorophyll *a* content (b) (cf. Table I)

3. Results and discussion

The mean values of the alimentary tract filling (*ATF*) of *E. superba* ranged in this region from 2.20 to 4.87 (Table I). The highest values were recorded in the region northward of the South Shetland Islands (4.21) and in the western region of the area under investigations (4.11). The lowest values of the ATF averaging 3.42, and the greatest differences in these values occured in the populations of krill caught in the Bransfield Strait, especially in its eastern part (Fig. 1). The biomass of krill determined in these three aubregions of the area under investigations was exactly opposite. The

Table I.

Alimentary tract filling (*ATF*) of krill population in relation to the chlorophyll *a* concentration in the region of the southern Drake Passage and the Bransfield Strait, February–March 1981

Station No. (krill hauls)	Date	Mean ATF	Chlorophyll *a* (mg under 1 m^2) 0—150 m	integrated in water layers 0—100 m	Date	Station No. (chlorophyll *a* measurements)
7	16 Feb.	3.44	49.7	46.5	15 Feb.	6
9	16 Feb.	3.24	86.5	79.8	16 Feb.	8
12	17 Feb.	4.66	97.5	89.75	16 Feb.	11
14	17 Feb.	4.84	203.4	190.2	17 Feb.	14
26	20 Feb.	4.19	—	—	—	—
28	20 Feb.	4.06	43.7	36.5	20 Feb.	27
30	20 Feb.	4.45	—	—	—	—
31	20 Feb.	4.03	66.3	49.8	—	—
42	23 Feb.	4.26	87.4	79.2	23 Feb.	40
43	23 Feb.	3.68	171.1	161.4	23 Feb.	44
52	25 Feb.	3.77	—	—	—	—
53	25 Feb.	4.87	84.3	71.1	—	—
63	28 Feb.	4.50	75.7	64.0	27 Feb.	62
67	28 Feb.	2.20	25.3	18.8	—	—
70	4 Mar.	2.86	49.7	42.7	—	—
74	5 Mar.	4.04				
75	5 Mar.	4.05	25.3	17.6	—	73
77	5 Mar.	2.83	35.9	29.7	—	—
78	6 Mar.	4.49	—	—	—	—
80	6 Mar.	3.98	—	—	—	—
83	6 Mar.	4.23	—	—	—	—
84	6 Mar.	2.53				
91	9 Mar.	3.45	27.9	19.7	9 Mar.	90
93	9 Mar.	3.27	—	—	—	—
94	9 Mar.	3.69	50.3	43.7	—	—
99	10 Mar.	4.10	—	—	—	—
95	10 Mar.	3.93	105.7	92.2	10 Mar.	97
100	10 Mar.	2.60	37.5	27.5	—	—
101	11 Mar.	2.31	—	—	—	—
106	12 Mar.	3.01	—	—	—	—
110	12 Mar.	4.04	—	—	—	—
111	12 Mar.	2.86	—	—	—	—
112	14 Mar.	3.80	—	—	—	—
120	15 Mar.	3.47	—	—	—	—
123	15 Mar.	3.55	—	—	—	—

quantities of chlorophyll *a*, expressed by the values integrated for the water column of 0–150 m under 1 m^2 of sea surface, ranged from 25.3 to 203.4 mg. The highest values of chlorophyll *a* averaging 104.6 mg were recorded in the region northward of the South Shetland Islands, whereas in the western region of the investigated area 91.1 mg, and in the Bransfield Strait 44.7 mg. In general, chlorophyll *a* content corresponds to the picture of distribution of the wet and dry weight of seston, the numbers of photoplankton cells, and algal biomass (Kopczyńska and Ligowski 1982).

In the Bransfield Strait, where the highest values of krill biomass were recorded, seston and large diatoms were scarce. The main mass of phytoplankton was probably composed of small forms, *Flagellata* and "monads". At various stations of the Bransfield Strait, particular matter, net phytoplankton and chlorophyll *a* content in the water showed great variety and patchy distribution.

The comparison of the mean *ATF* values for various krill swarms with the quantities of chlorophyll *a* (Table I, Figs. 2 and 3) indicates similar

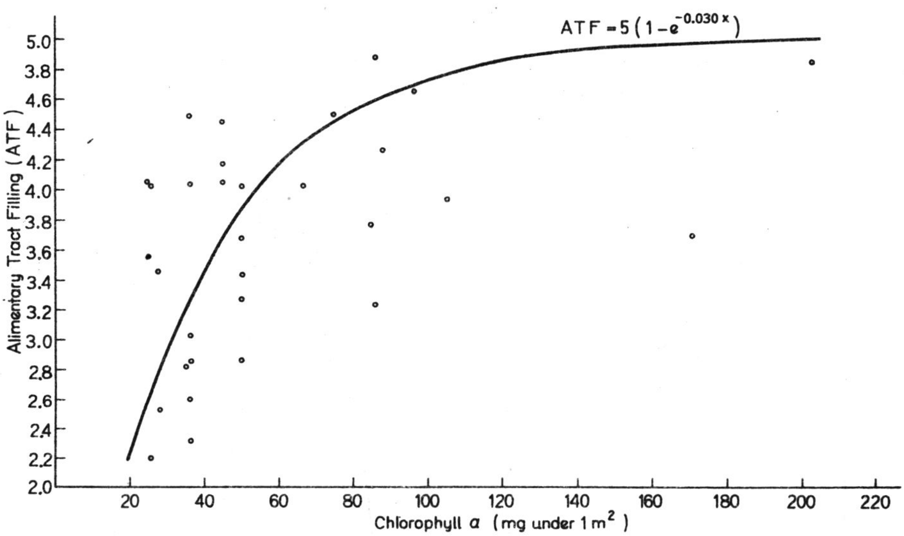

Fig. 2. Relation between the mean value of alimentary tract filling and the quantity of chlorophyll *a* in 0–150 m water layer

relation as that of food ration dependence on the quantity of food concentration in *Euphausiacea* (Parsons, Le Brasseur and Fulton 1967, Araškevič et al. 1980), as described by Ivlev's equation: $r = R(I - e^{-kp})$. Using this formula for the description of the *ATF*/ch *a* relation gave positive results. In this equation: r — *ATF*, R — $ATF_{max} = 5$, p — chlorophyll *a*, k — coefficient determined by fitting. The coefficient of correlation between the *ATF* and chlorophyll *a* values in water column of 0–150 m and 0–100 m is 0.84 and 0.79, respectively. The *ATF* is highly dependent to 60 mg (Figs. 2 and 3), above that value the *ATF* varies considerably.

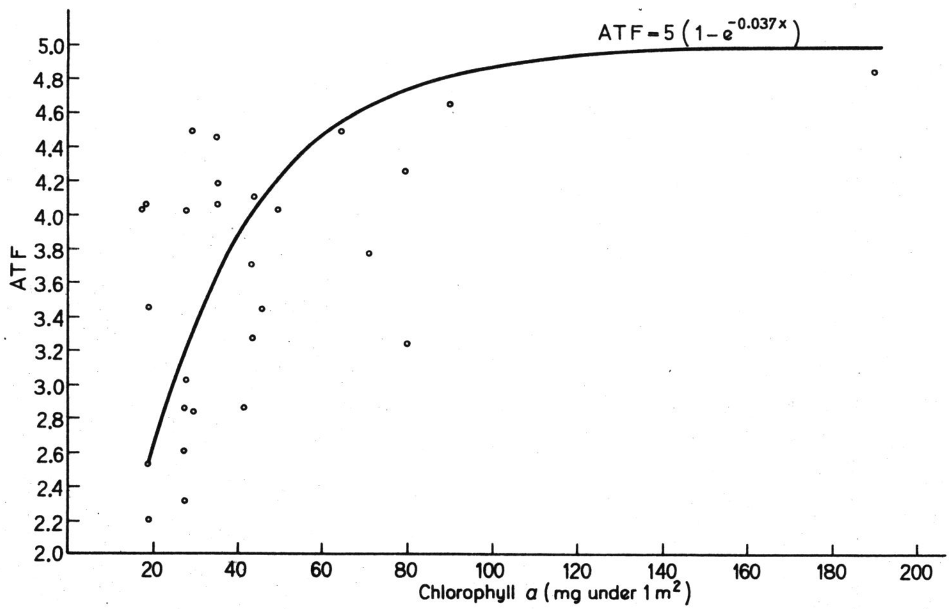

Fig. 3. Relation between the mean value of alimentary tract filling and quantity of chlorophyll *a* in 0–100 m water layer

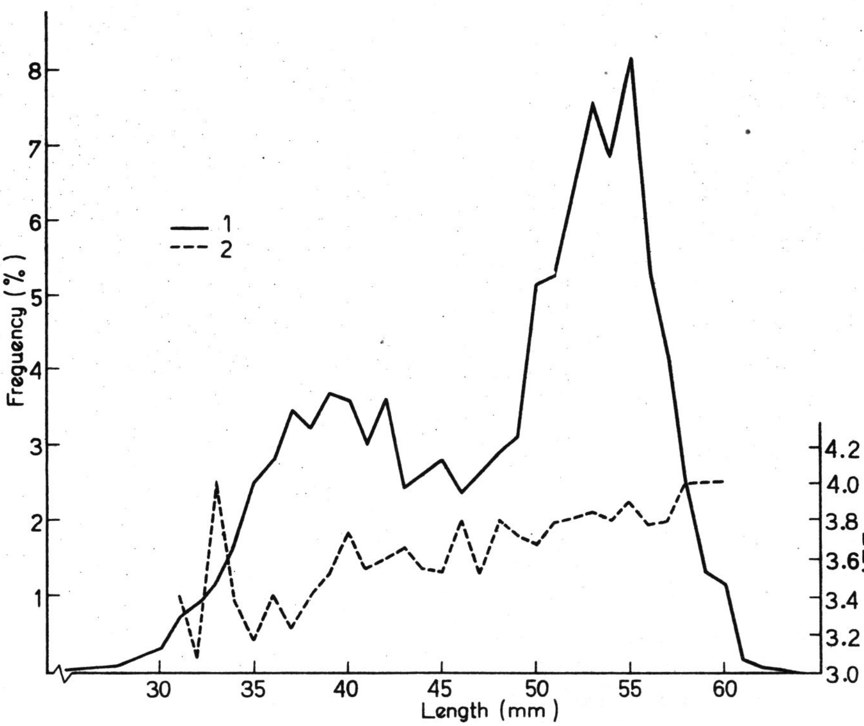

Fig. 4. Distribution of krill body length (1) in the region under investigations (3500-individuals) and mean value of alimentary tract filling (2) in various length-groups

The mean *ATF* values calculated for various length-classes in the analysed material of 3500 individuals (Fig. 4) show an increase with the increase of the body length of the specimens. The increase of the *ATF* values seems to have a nonlinear character and to be proportional to the increase of the body weight of krill. This is associated with the fact of quicker increase of the body weight than of the body length of krill $W_w = 0.0018L^{3.3831}$ (cf. Rakusa-Suszczewski 1981). The value of food ration (in this case the *ATF* value) is proportional to the body weight and may be described by equation: $C = aW^b$, where: C — amount of food, W — body weight, a and b — coefficients (Rakusa-Suszczewski and Uchmański)[2]). The *ATF* values in the range of 31–60 mm length — classes confirm this dependence to the full. In our case the correlation between *ATF* and body wet weight of krill is high $R = 0.76$, $N = 30$, and can be described on log-log scale by equation: $ATF = 2.45\,W_w^{0.064}$ $\Delta a = 0.09$, $\Delta b = 0.014$, W_w — in mg.

The 24-hour rythm of the ATF of the investigated krill swarms (Table I, Fig. 5) is more strongly marked then when the *ATF* mean values exceed the range of 3.8–4.0 on the adopted 5 — degree scale, which corresponds to the quantities of about 60 mg of chlorophyll *a* content in the water column from 0 to 150 m depth under 1 m^2 of the sea surface. The *ATF* mean values given by Kalinowski and Witek (1980) in accordance with the 5-degree scale, corroborate the picture of the 24-hour *ATF* rythm of

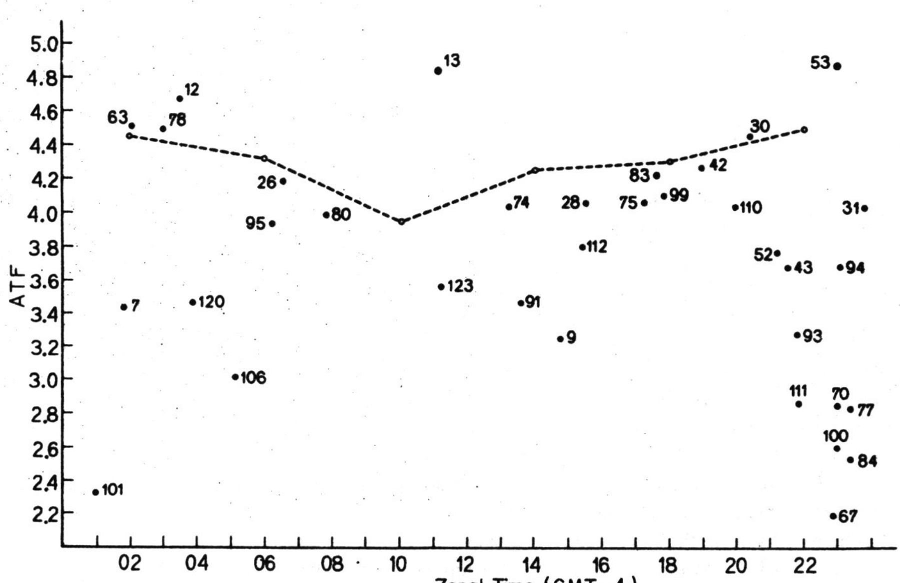

Fig. 5. Mean values of alimentary tract filling at various hours of day and night Dashed line connects the mean ATF values, illustrating the 24-hour feeding rythm of krill, given by Kalinowski and Witek (1980).

[2]) Rakusa-Suszczewski S., Uchmański J. — Standarization of the description of bioenergetic processes in *Euphausia superba* Dana. BIOMASS — Handbook No. 15, SCAR/SCOR/IABO/ACMRR.

krill obtained in this study (Fig. 5), however, when food in the environment is scarce, the 24-hour feeding rythm decline.

4. Резюме

Исследования проводились в районе пролива Дрейка и пролива Брансфилда в феврале и марте 1981 года в рамках экспедиции БИОМАСС-ФИБЭКС. Зависимость между степенью выполнения желудочно-кишечного тракта (*ATF*) криля фекальной массой в масштабе 1—5 и количеством хлорофилла *a*, интегрированного в слое 0—150 м можно описать согласно с уравнением Ивлева: $ATF = 5\,(1 - e^{-0,03x})$; x — хлорофилл *a* (мг под поверхностью 1 м²). Величина *ATF* пропорциональна массе тела криля и описана уравнением $ATF = 2,45\ W_w^{0,064}$ (W_w в мг). Суточный ритм питания криля зависит от количества пищи в среде и исчезает при его недостатке.

5. Streszczenie

Badania prowadzono w rejonie Cieśniny Drake'a i Cieśniny Bransfielda w lutym i marcu 1981 roku w ramach wyprawy BIOMASS-FIBEX. Związek pomiędzy stopniem wypełnienia przewodu pokarmowego (*ATF*) kryla masą fekalną w skali 1—5 a ilością chlorofilu *a* integrowanego w warstwie 0—150 m można zapisać zgodnie z równaniem Ivleva: $ATF = 5\,(1 - e^{-0,03x})$; x — chlorofil *a* (mg pod 1 m²). Wartość *ATF* jest proporcjonalna do masy ciała kryla opisana jest równaniem $ATF = 2,45\ W_w^{0,064}$ (W_w w mg). Rytm dobowy odżywiania kryla zależy od ilości pokarmu w środowisku i zanika przy jego niedostatku.

6. References

1. Antezana T., Ray K., Melo C. 1982 — Trophic behaviour of *Euphausia superba* Dana in laboratory conditions. Polar Biol. 1 (2): 77–82.
2. Araškevič J. G., Kachun L., Nikolajeva G. G., Pelymskij A. G., Ponomareva L. A. 1980 — Kačestvennajv i količestvennaja charakteristika pitanija masovych vidov planktonnych životnych (In: Ekosistemy pelagiali peruanskogo rajona, Eds. Izd. Nauka), Moskva, 202–215.
3. Barkley E. 1940 — Nahrüng und Filterapparat des Walskrebschens *Euphausia superba* Dana — Z. Fischerei. Beih., 1: 65–156.
4. Everson I., Ward P. 1980 — Aspects of Scotia Sea zooplankton (In: Ecology in the Antarctic, Eds. W. N. Bonner and R. J. Berry) Academic Press. London, 91–101.
5. Jeffrey S. W., Humphrey G. F. 1975 — New spectrophotometric equations for determining chlorophylls *a*, *b*, *c* and c_2 in higher plants, algae and natural phytoplankton — Biochem. Physiol., Pflanzen, 167: 191–194.
6. Kalinowski J., Witek Z. 1980 — Diurnal vertical distribution of krill aggregations in the Western Antarctic — Pol. Polar Res., 1 (4): 127–146.
7. Kawamura A. 1981 — Food habits of *Euphausia superba* and the diatom community — BIOMASS, II. Published by SCAR/SCOR Cambridge, 55–68.
8. Kopczyńska E., Ligowski R., 1982 — Phytoplankton abundance and distribution in the southern Drake Passage and the Bransfield Strait, in February–March 1981 BIOMASS-FIBEX — Pol. Polar Res. 3 (3–4): 193–202.
9. Mężykowski T., Rakusa-Suszczewski S. 1979 — The circidian rythms in *Euphausia superba* Dana and its carbohydrate metabolism — Meeresforsch., 27 (2): 124–129.

10. Parsons T. R., Le Brasseur R. J., Fulton J. D. 1967 — Some observations on the dependence of zooplankton grazing on the cell size and concentration of phytoplankton blooms — J. Oceanogr. Soc. Japan, 23 (1): 10–17.
11. Pavlov V., Ja. 1969 — Pitanie krilja i nekotoryje osobennosti ego povedenija — Trudy VNIRO, 66: 206–221.
12. Pavlov V., Ja. 1974 — O charaktere svjazi meždu pitaniem i nekotorymi osobennostjami povedenija *Euphausia superba* Dana — Bonitet Mirovogo Okeana, 5 (99): 104–116.
13. Rakusa-Suszczewski S. 1981 — Polish Antarctic expedition 1975/76 — BIOMASS, II. Published by SCAR/SCOR Cambridge, 151–155.

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