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Ryszard LIGOWSKI
Department of Algology, Institute of Environmental Biology,
University of Łódź, Banacha 12/16, 90-237 Łódź

Phytogenic food of *Euphausia superba* Dana caught in the southern Drake Passage and the Bransfield Strait, February—March 1981 (BIOMASS-FIBEX)*)

ABSTRACT: The phytogenic food composition in the stomachs of *Euphausia superba* Dana, caught at 18 sampling stations in the Antarctic part of the Atlantic Ocean, was analysed. The material used was taken from krill catches made from the board of the r/v "Profesor Siedlecki" in the sector "A" of the BIOMASS-FIBEX Programme, in February and March 1981. In the food of *Euphausia superba* 70 algal taxa were identified, including 68 taxa belonging to *Bacillariophyceae* and two to *Chrysophyceae*. Planctonic diatoms were the main component of the food of *Euphausia superba*. Single benthic diatoms were found occasionally.

Key words: Antarctic, *Euphausia superba*, food, phytoplankton

1. Introduction

The food taken by *Euphausiidae* (Mauchline and Fisher 1969) is divided into three groups: 1. diatoms, *Dinoflagellatae* and *Tintinnidae*; 2. zooplankton; 3. detritus. The organisms found in the stomachs of *Euphausia superba* prove that it feeds mainly on phytoplankton (Marr 1962). According to Mauchline and Fisher (1969) *Euphausia superba* is the only species of *Euphausiidae*, in the food of which phytoplankton prevails. At the same time those authors suggest that in case of the lack of phytoplankton utilization of another kind of food by *E. superba* is possible. Pavlov (1969) deems that phytoplankton is the main component of the food of *Euphausia superba*. A comparison of fatty acids in phytoplankton and in

*) These studies were carried out on board of the r/v "Profesor Siedlecki" within the Programme MR-I-29A of the Polish Academy of Sciences, during the Antarctic Expedition headed by Dr. S. Rakusa-Suszczewski.

Euphausia superba confirms the phytophagy of this species (Bottino 1975). Dzik and Jażdżewski (1978) report likewise that diatoms are the main component of the food of *Euphausia superba*, while the hypothesis that in winter this species may feed on zooplankton and detritus was not verified. Most of the analyses of the *E. superba* stomach contents were made in the material collected in summer. Mauchline and Fisher (1969) suppose that in autumn and in winter the composition of the food may be different. The importance of diatoms, *Fragilariopsis antarctica* (*Nitzschia kerguelensis*) especially, in the food of *Euphausia superba* is emphasized by Barkley (1940) and Marr (1962). Hart (1934, 1942), Hustedt (1958), Pavlov (1969, 1971a, 1971b) found in the qualitative analysis of the food composition of *Euphausia superba* a great variety of algal species, mostly diatoms.

The aim of these studies was the identification of the species composition of algae in the food of *Euphausia superba* and determination of the ratio of various taxa in different regions of the investigated sector.

2. Material and methods

The material used for microscopic analysis of the stomach contents of *Euphausia superba* was collected during oceanological investigations carried out on board of the r/v "Profesor Siedlecki" in February and March 1981, in the sector "A" of the BIOMASS-FIBEX Programme in the Atlantic Ocean. For investigations krill specimens collected at 18 sampling stations were used (Fig. 1). At 15 stations: Nos. 9, 12, 13, 26, 28, 30, 42, 43, 52, 63, 74, 75, 91, 93, and 101, the samples were taken from trawl hauls, while at 3 stations: Nos. 31, 70 and 94 *Euphausia superba* specimens were caught with Bongo net. The stations were located between 65°8.5′S and 61°48.1′S and 66°7.4′W and 56°26.2′W (Fig. 1) (Rakusa-Suszczewski 1982).

Shortly after the collection of the samples the carapaces of the specimens were torn off and their stomachs removed and fixed in 4% formaldehyde. The presented results were obtained from the analyses of the stomach contents of several specimens from each station. Temporary microscopic slides were prepared directly after the collection of the stomachs, fragments of tissues were removed and stomach contents were spread on the microscopic object glass. Permanent, pleurax slides were made of the food contents from preserved stomachs. They were of a sufficiently good quality, since in the stomachs of *Euphausia superba* there were usually present empty algal cells, mostly diatoms. The imperfection of the slides, sometimes making observation difficult, consisted in the presence of mineral particles and fragments of the stomach itself. The attempted calcination of these artifacts with various methods used in preparation of diatoms (Siemińska 1964, Kalbe 1974) did not give the requested results. Algae were identified making use of the following studies: Schmidt (1875—1959), Karsten (1905) Mangin (1915), Heiden and Kolbe (1928), Hendey (1937), Hustedt (1927—1959, 1958), Cleve-Euler (1953—1955), Frenguelli (1960), Jouse,

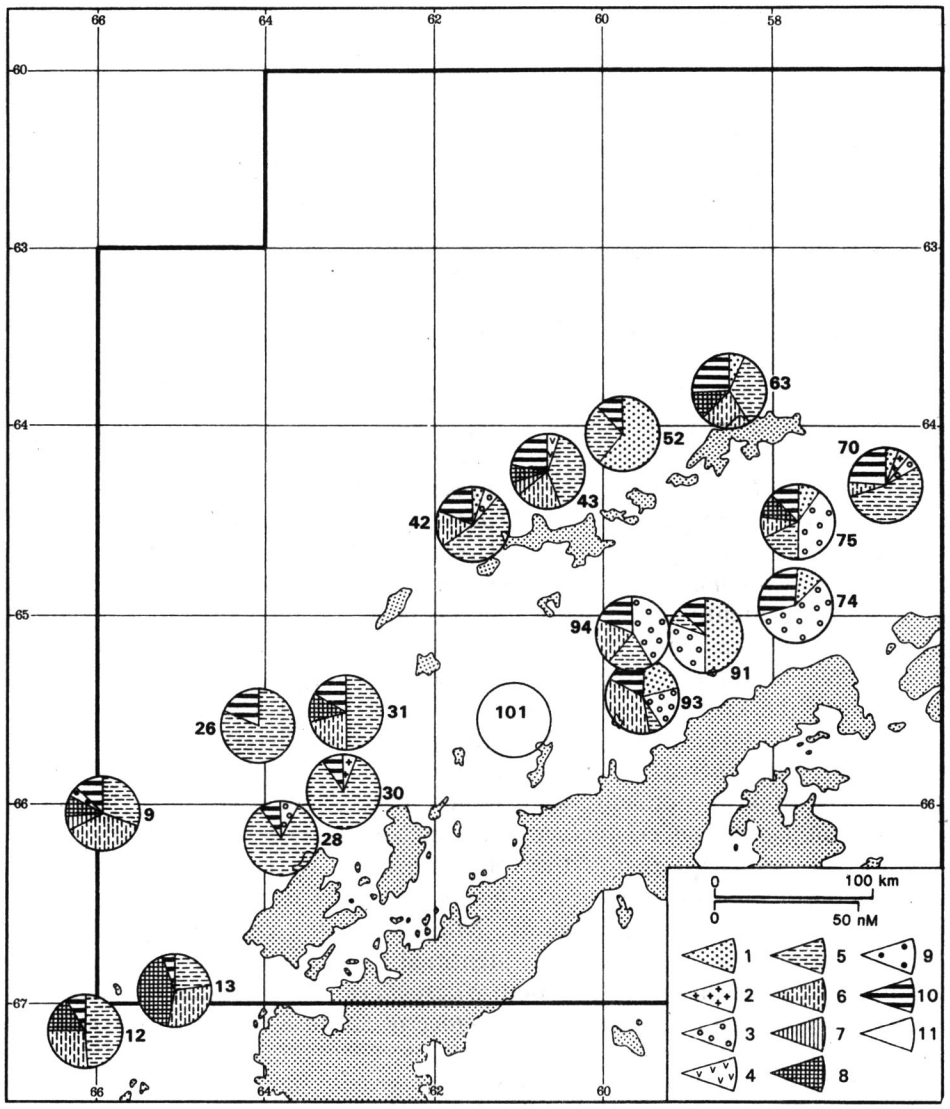

Fig. 1. Algae dominating in the food of *Euphausia superba* in the sector "A" of the BIOMASS-FIBEX Programme

1 — *Chaetoceros* sp., 2 — *Charcotia actinochilus*, 3 — *Coscinodiscus* sp., 4 — *Dictyocha speculum*, 5 — *Nitzschia curta*, 6 — *Nitzschia cylindrus*, 7 — *Nitzschia kerguelensis*, 8 — *Nitzschia* sp., 9 — *Thalassiosira gracilis*, 10 — other species, 11 — empty stomachs.

Koroleva and Nagaeva (1962), Kozlova (1962, 1964), Hasle (1965, 1972), Abbott (1974), Pankov (1976), Atlas microorganizmov (1977). To determine the percentage of various taxa of diatoms over 300 cells were counted in each slide (Cholnoky 1968, Kalbe 1974). A part of the cells found in the stomachs was in fragments. Therefore an approximate percentage of the algal taxa in the stomachs was calculated. Algae represented in

a ratio of $\geqslant 5\%$ in relation to the total number of algae are regarded as dominant organisms at the given station.

3. Results and discussion

In the exmined stomachs of *Euphausia superba* 70 algal taxa were found (Table I). Diatoms (class *Bacillariophyceae*) prevailed in the species composition — 68 taxa were identified. The remaining 2 species belong to the class *Chrysophyceae*. The identification of the algal cells from the stomachs of *Euphausia superba* is difficult due to the crushing of the cells into fragments in the alimentary tract. Larger cells, thin-walled or with long processes, were found always in fragments, sometimes very small. Barkley (1940) observed in krill stomachs the genera: *Corethron*, *Chaetoceros* and *Rhizosolenia* only in fragments. Larger diatoms with long cells, such as *Synedra* and *Thalossiothrix*, were present mostly in fragments; whereas cells with long processes, such as *Chaetoceros*, were found only as fragments of setae or as cells without setae (Hustedt 1958). In our studies moreover the genera: *Coscinodiscus*, *Thalassionema* and *Nitzschia* were also observed in fragments. Identification made on the basis of the remaining fragments of the cells was in many cases possible to the category of the genus, only. The degree of the crushing of the algae depends on the number of cells falling into the krill filtratory basket (Pavlov 1969). That author observed few unbroken large cells in the filtratory basket in the regions rich in phytoplankton, whereas in the regions poor in phytoplankton most of the cells found in krill stomachs were intact; even such large and fragile cells as those of *Corethron criophilum* were unchanged.

In the investigated region the following algae were recorded most often in the food of *Euphausia superba: Chaetoceros* sp., *Charcotia actinochilus*, *Corethron criophilum*, *Coscinodiscus* sp., *Nitzschia curta*, *Nitzschia cylindrus*, and *Nitzschia* sp. (Table I). Among the identified algal taxa 9 were determined as the organisms dominating in the food. *Nitzschia curta* dominated in 15 stations, *Nitzschia cylindrica* in 11 stations, *Chaetoceros* sp. in 8 stations, *Coscinodiscus* sp. in 8 stations, *Nitzschia* sp. in 7 stations, *Charcotia actinochilus* in 2 stations, *Nitzschia kerguelensis*, *Thalassiosira gracilis* and *Dictyocha speculum* in one station, each (Table I). Barkley (1940) suggests that the food of *Euphausia superba* is selected with preference of small forms and forms without processes. Nemoto (1968) and Kawamura (1981) are of the same opinion. Selectivity of sizes and forms of the food in *Euphausiidae* was also reported by Weigmann after Nemoto (1972). Kawamura (1981) is of the opinion that *E. superba* prefers the waters in which small diatoms prevail. Hart (1934, 1942) emphasizes krill capability of feeding on large forms, however, they are more difficult to identify due to a strong disintegration of the cells. Hustedt (1958) found in the food contents mainly the species of the genus *Fragilariopsis* (class *Pennatae*) and small diatoms of the class *Centricae*. Diatoms with long processes, though observed in the food, were avoided by *Euphausia superba*. In the list of forms observed in the stomachs of *Euphausia superba* Barkley (1940) and Marr (1962) mentioned species

Table I

Composition of algae in the food of *Euphausia superba* Dana in the sector "A" BIOMASS-FIBEX expedition

No. of station	9	12	13	26	28	30	31	42	43	52	63	70	74	75	91	93	94
Trawling depth (m)	80–50	32–20	35–5	64–45	40–20	40–25	10–0	45–20	40–20	50–35	30–15	15–0	50–35	60–17	40–20	38–10	15–0
Water depth (m)	433	500	502	261	193	350	314	130	120	168	193	970	512	320	160	840	850
Bacillariophyceae																	
Achnanthes sp.					+				+				+	+	+		
Actinocyclus sp.				+													
Amphiprora sp.		+															
Amphora sp.			+		+								+		+		
Asteromphalus hookeri Ehr.		+							+								
A. hyalinus Karst.	+								+	+	+						
A. parvulus Karst.	+	+	+														
Biddulphia sp.		+	+		+	+	+		+	+			+	+	+		
Chaetoceros atlanticus Cl.	+	+	+								+					+	+
C. bulbosus Heiden														+			
C. concavicornis Mangin			+														
C. criophilus Castr.	+	+			+	+	+	+	+		+						
C. dichaeta Ehr.			+											+	+		
C. neglectus Karst.			+														
Chaetoceros sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
Charcotia actinochilus Hust.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cocconeis costata Greg.			+		+	+		+	+	+			+	+	+	+	+
C. curiosa Hust.									+							+	+
C. imperathrix A.S.													+	+			
C. sparsipunctata Brun.													+				
Cocconeis sp.			+		+	+		+	+				+	+	+		
Corethron criophilum Castr.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
Coscinodiscus bouvet Karst.							+				+					+	+
C. furcatus Karst.					+									+	+	+	
C. inflatus Karst.		+											+	+		+	
C. lentiginosus Jan.	+	+	+	+	+				+	+	+	+			+		
C. oculoides Karst.													+				
C. symbolophorus Grun.		+	+	+	+	+		+					+				
C. tabularis Grun.	+			+		+		+						+	+		
Coscinodiscus sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
Dactyliosolen antarcticus Castr.		+	+													+	+
Entopyla sp.					+												
Eucampia balaustium Castr.		+	+	+			+	+	+		+	+	+	+			
Gomphonema sp.		+	+		+			+	+	+		+	+	+	+	+	
Grammatophora angulosa Ehr.					+	+		+					+	+	+		
Grammatophora sp.					+	+		+									
Licmophora sp.								+	+				+	+			
Navicula criophila De Toni	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
N. diploneiformis Hust.									+						+	+	
N. directa W.Sm.							+	+	+								
Navicula sp.	+	+	+					+	+	+	+	+					+
Nitzschia curta (Hust.) Hasle	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
N. cylindrus (Gran) Hasle	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
N. kerguelensis (Hust.) Hasle	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+
N. obliquecostata (V. Heurck) Hasle	+	+	+	+	+		+	+	+	+	+		+	+	+	+	+
N. rhombica (Hust.) Hasle	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+
N. ritscherii (Hust.) Hasle		+	+	+			+	+				+					
N. sublinearis (Hust.) Hasle	+	+	+	+	+	+	+	+	+	+	+	+	+	+			
N. vanheurckii (Hust.) Hasle									+							+	+
Nitzschia sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
Pinnularia quadratarea A.S.														+		+	+
Porosira pseudodenticulata (Hust.) Jouse								+			+		+				
Rhizosolenia alata Bright.	+										+					+	
R. alata f. *curvirostris* Gran.		+															
Rhizosolenia sp.		+	+					+	+	+							
Rouxia sp.										+							
Schimperiella antarctica Karst.	+			+	+					+	+						
Thalassionema elegans Hust.	+	+	+	+	+	+	+	+	+	+	+			+	+		
T. nitzschioides Grun.				+					+				+	+	+	+	+
Thalassionema sp.										+	+	+					
Thalassiosira antarctica Comber										+	+				+		
T. gracilis Hust.	+	+	+	+	+	+		+	+	+	+	+		+	+		+
Thalassiosira sp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
Thalassiothrix antarctica Cl. et Grun	+	+	+	+	+	+	+	+	+	+	+	+		+	+		
Trachyneis aspera Cl.								+							+	+	+
Triceratium sp.				+	+								+	+	+		
Tropidoneis glacialis Heiden			+														
Tropidoneis sp.	+	+	+				+	+	+								
Chrysophyceae																	
Dictyocha speculum Ehr.	+	+	+	+	+		+	+	+	+	+	+		+			
Phaeocystis sp.		+															
Other																	
filamentous undetermined							+	+	+								

with large or long cells. Pavlov (1971 b) observed that krill feeds on setaceous forms at least as much as on small cells and cells without processes. In our studies, also, the examined food of *Euphausia superba* showed fragments of *Corethron criophilum*, dominance of the species of the genus *Chaetoceros* in some samples and the occurrence of other large forms, such as: *Thalassiothrix antarctica, Dactyliosolen antarcticus, Cocconeis imperathrix, Triceratium* sp. and some species of the genus *Rhizosolenia.*

In the regions under investigation separate areas of the dominance of different algae may be differentiated in krill food. Species of the genus *Coscinodiscus* dominated in the food of *Euphausia superba* almost exclusively in the Bransfield Strait. Species of the genus *Chaetoceros* likewise were found in greater quantities only in the Bransfield Strait, except at the Station No. 52 located north of the South Shetland Islands (Fig. 1). The ratio of the species of the genus *Nitzschia* was insignificant in the stomachs of *Euphausia superba* from the Bransfield Strait. Genus *Nitzschia* dominated nearly exclusively at the stations located in the Drake Passage and west of Anvers Island (Fig. 1). Dominance of *Corethron criophilum* was observed in the net-samples collected in the Bransfield Strait (Kopczyńska and Ligowski 1982). Barkley (1940) reports smaller variety of species in the food of krill from the Bransfield Strait, as compared with nearby regions. He has not observed *Fragilariopsis curta (Nitzschia curta)* in the food of krill from that area. At the same time he has demonstrated that *Fragilariopsis antarctica* (*Nitzschia kerguelensis*) is the dominant species in the food of krill from the Bransfield Strait. In our studies this species was observed in very small numbers.

Though typically planktonic diatoms were the main component of the phytogenic food of krill the presence of the species of genus *Rouxia* in the stomachs of *Euphausia superba* collected at the Station No. 52 is worth mentioning. This is a fossil (Šešukova-Poreckaja 1967) found in the bottom sediments of the Antarctic (Heiden and Kolbe 1928, Jouse, Koroleva and Nagaeva 1962, Abbott 1974). At some stations single benthic algae of the genera: *Achnanthes, Amphora, Cocconeis, Entopyla, Gomphonema, Grammotophora, Licmophora, Pinnularia, Trachyneis* and *Triceratium* were also observed in the food contents (Table I).

The presence of the genus *Rouxia* and benthic genera of diatoms in the food seems to corroborate the possibility of *Euphausia superba* preying for food at the sea bottom (Mauchline and Fischer 1969). Yet at the stations where benthic algae were observed the depth of the sea down to the bottom ranged from 120 to 500 metres, while the depth of trawling was from 50 to 20 metres downwards. The presence of benthic algae in neritic plankton taken in by krill cannot be excluded, though benthic algae were found only in very few net-samples of phytoplankton collected at the same time in the investigated waters from the depth of 100 metres up to the water surface (Kopczyńska and Ligowski 1982). Pavlov (1974) suggests that the most active feeding of *Euphausia superba* occurs in the upper water layer of 15 metres below the surface and is of the opinion that at the depth of 40—50 metres *Euphausia superba* practically does not feed at all. According to that author the specimens caught at the depth

of 180 and 300 metres did not feed for 48 hours, at least. Hardy and Gunther (1935) and Marr (1962) report that in the daytime krill was observed at the depth of 160 metres. Kalinowski and Witek (1980) recorded the presence of the swarms of *Euphausia superba* down to the depth of 100–120 metres, but during the intensive night-feeding they appearared in the upper water layer.

In the samples from the Station No. 101 the stomachs of *Euphausia superba* were empty (Fig. 1). These samples were collected at 24 00 h, i.e. at the time when *Euphausia superba* should show the highest feeding activity (Pavlov 1969, 1974; Kalinowski and Witek 1980).

In the food of krill, besides the algae with durable cell walls, such as diatoms and species of the genus *Dictyocha*, there were also species of the genus *Phaeocystis* with less resistant cell walls. This genus was identified only in the nonpreserved slides made shortly after the catch. Pavlov (1971b) alleges that it is not possible to identify the thin-walled forms of diatoms in the preserved stomach contents. Thus, it appears that identification of algae in the food of *Euphausia superba* should be made soon after the catch.

4. Резюме

Изучалось содержание желудков *Euphausia superba*, пойманных тралом и сетью Бонго с НИС "Професор Седлецки" в ходе реализации программы БИОМАСС-ФИБЭКС в феврале и марте 1981 г. Станции находились в антарктической части Атлантического океана вблизи Южных Шетландских о-вов (рис. 1). Желудки извлекались из только что пойманных особей. В содержании желудков *Euphausia superba* было определено 70 таксонов, в том числе 68 диатомей (Таблица I). Чаще всего и при том найболее численно наблюдались диатомеи: *Nitzschia curta, Nitzschia cylindrus, Nitzschia* sp., *Chaetoceros* sp., *Coscinodiscus* sp. В проливе Брансфилда преобладали роды *Coscinodiscus* и *Chaetoceros*, в проливе Дрейка и к западу от острова Анверс — виды рода *Nitzschia*. Значительная часть обнаруженных в желудках диатомей была раздроблена, и их идентификация была возможна только на основе сохраненных фрагментов. Главным компонентом растительной пищи *Euphausia superba* являлись планктонные диатомеи. Случайно встречались также бентосные диатомеи.

5. Streszczenie

Badano zawartość żołądków *Euphausia superba* pobranych trałem przemysłowym i siatką Bongo nr r/v „Profesor Siedlecki" w czasie realizacji programu BIOMASS-FIBEX, w lutym i marcu 1981 r. Stacje wyznaczone były w części antarktycznej Oceanu Atlantyckiego w okolicach Szetlandów Południowych (rys. 1). Żołądki pobierano ze świeżo złowionych osobników. W pokarmie *Euphausia superba* zidentyfikowano 70 taksonów glonów, w tym 68 okrzemek (tabela I). Najczęściej i najliczniej w pokarmie występowały okrzemki: *Nitzschia curta, Nitzschia cylindrica, Nitzschia* sp., *Chaetoceros* sp., *Coscinodiscus* sp. W Cieśninie Bransfielda dominowały rodzaje *Coscinodiscus* i *Chaetoceros*, w Cieśninie Drake'a i na zachód od wyspy Anvers przeważały gatunki z rodzaju *Nitzschia*. Wiele okrzemek obecnych w żołądkach było rozdrobnionych, a ich identyfikacja odbywała się na podstawie zachowanych fragmentów. Głównym składnikiem pokarmu roślinnego *Euphausia superba* były okrzemki planktonowe. Pojedyńczo występowały okrzemki bentosowe.

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