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Structure and biomass of zooplankton between King George Island and Elephant Island (BIOMASS III, October—November 1986)

ABSTRACT: Zooplankton in the water column from the surface to bottom was studied. Copepods were the dominating organisms. Average zooplankton biomass was about 5 g in 1000 m^3. The highest zooplankton density occurred between 300 and 600 m. The influence of the Scotia Front on the horizontal and vertical distribution of zooplankton is discussed.

Key words: Antarctica, zooplankton, Scotia Front BIOMASS III.

1. Introduction

Species composition of Antarctic zooplankton is well known (Voronina 1984). Its diversity is comparatively low (Mackintosh 1934; Hardy and Gunther 1935); most zooplankton species have a circumpolar distribution pattern and the majority of mass occurring taxa undertake seasonal vertical migrations (Mackintosh 1934; Voronina 1984). Antarctic zooplankton biomass is characterized by a comparatively large biomass in comparison to subantantarctic waters (Foxton 1956). Considerable differences between various Antarctic areas in zooplankton distribution and biomass were frequently noted, the differences connected with seasonal environmental changes and different hydrological conditions in particular areas (i.a. Foxton 1956; Jażdżewski, Kittel and Łotocki 1982; Witek et al. 1985). Especially interesting regions are those of high water masses dynamics and considerable gradients of physical and chemical factors, i.e. so called frontal zones. One of them is the region of Southern Ocean situated to the north-east of the Antarctic Peninsula and South Shetland Islands. In this area Pacific water masses

(West Wind Drift) mix with the Weddell Sea waters (Weddell Drift), forming a zone of complicated dynamics and called Weddell-Scotia Confluence (Gordon 1967; Gordon, Georgi and Taylor 1977; Patterson and Sievers 1980; Stein and Rakusa-Suszczewski 1983). Scotia Front is a northern border of this area (Gordon, Georgi and Taylor 1977). This front runs along the north-western slope of the shelf of King George and Elephant Islands (South Shetlands) displaying only slight seasonal and multiannual position changes (Stein 1986).

In the present paper zooplankton composition and its biomass distribution is treated in the water column of the area comprising a small sector of the Weddell-Scotia Confluence, situated over the north-western slope of the Elephant Island shelf (Fig. 1). Our results constitute a part of the program of the BIOMASS III expedition (Rakusa-Suszczewski 1988a). Hydrological characteristics of the investigated water column is presented by Grelowski and Wojewódzki (1988) and Rakusa-Suszczewski (1988b).

Zooplankton of the west Antarctic region was studied several times already (for instance Mackintosh 1934; Orensanz, Ramirez and Dinofrio 1974; Jażdżewski, Kittel and Łotocki 1982; Mujica and Torres 1982; Witek et al. 1985; Nast 1986). Nast (1986) has discussed the distribution of chosen zooplankton groups in connection with the location of the frontal zone of the Weddell-Scotia Confluence. The distribution of particular planktonic groups in the Scotia Front is also treated in this volume (Kittel 1988 — Euphausiacea, Siciński 1988 — Polychaeta, Żmijewska 1988 — Copepoda).

2. Material and methods

Plankton samples were collected in an area situated south-west of the Elephant Island from October 31st to November 3rd, 1986, in 9 stations distributed along 3 transects: transect I — stations 48, 47 and 46; transect II — stations 42, 43 and 44; transect III — stations 37, 38 and 39 (Fig. 1). Samples were collected using a Nansen net of the mouth diameter 70 cm (mouth surface area 0.38 m^2) and with mesh size 200 μm. Samples were taken in each station in several layers separately. The number and depth of the layers was established according to the precedent temperature characteristics (Grelowski and Wojewódzki 1988). Depth ranges of particular layer were usually between 0—100, 100—300, 300—600 and below 600 m, but actual limits were sometimes shifted (see Tab. 1). However for the sake of clarity we have used in the text above mentioned conventional, rounded ranges. Altogether 30 samples were taken. Material was preserved in the 4% formaline solution, in the laboratory taxa were segregated and their net weight was measured. The composition of zooplankton in particular layers of each

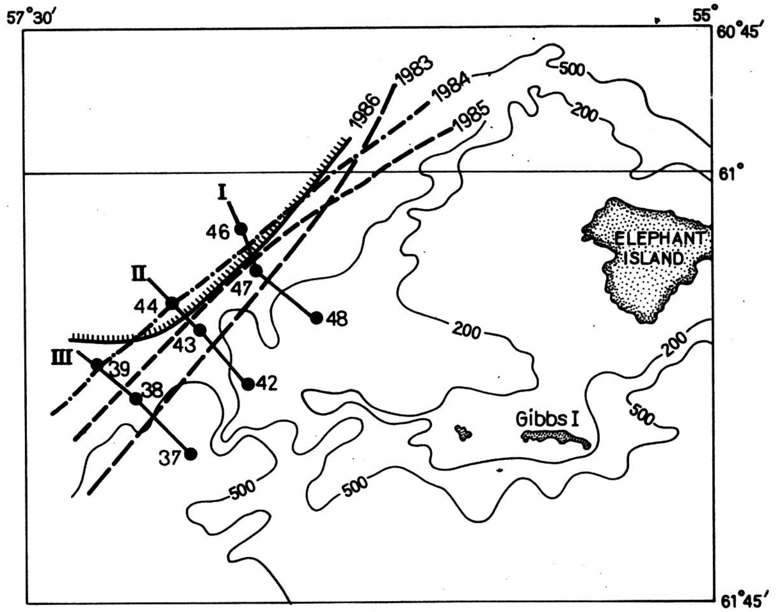

Fig. 1. Research area with oceanographic stations situated along three transects. Scotia Front position in 1983, 1984 and 1985 according to Stein (1986), in 1986 — according to Rakusa-Suszczewski (1988b)

station is presented in an Appendix. The dendrite analysis of the similarity of the stations with regard to the zooplankton composition and biomass distribution was carried out according to Romaniszyn (1970).

3. Results

Zooplankton assemblage of the investigated region (Appendix) is dominated by Copepoda, a group of the 100% frequency. Along with copepods the most frequent were Chaetognatha and Polychaeta, that were met however only sporadically in the uppermost layer. An important share in the biomass, along with Copepoda and Chaetognatha, had Salpae, Euphausiacea and Siphonophora. The share of remaining groups: Pteropoda, hydromedusae, Amphipoda, Mysidacea, Foraminifera, Ostracoda, decapod larvae and fish larvae was very low.

In the distribution of the biomass of particular taxa and of the total zooplankton some regularities were to be observed (Tabs. 1, 2; Figs. 2—5).

In the surface layer (0—100 m) the highest variability in biomass was noted (Tab. 2, Figs. 3—5). The index of dispersion (Tab. 2) was here 132%. In this water layer the maximal zooplankton biomass was found in station 47, medium biomass was observed in stations 37 and 38, whereas in other stations biomass values were low, with absolute minimum in station 39. In general zooplankton assemblage of this water layer can be defined as an impoverished one in comparison with deeper layers. The only regular compo-

Table 1

The horizontal biomass distribution of particular zooplankton taxa at four distinguished water layers. Salpae and Ctenophora are not included.

Sequence of the stations accordingly to their cenological similarity is based on the dendrites from Fig. 2.

Deph (m)	Taxon	Station								
		47	38	37	46	44	48	43	39	42
0—100 m	Copepoda	18,3	7,8	3,1	1,8	1,7	1,1	0,6	0,03	
	Euphausiacea	1,6	0,03	1,8	0,2			1,0	0,4	
	Polychaeta		0,02	0,03						
	Chaetognatha	0,03								
	Siphonophora					0,3				
	Pteropoda								0,02	
		48	47	42	39	43	38	37	44	46
100—300	Copepoda	3,5	2,2	1,9	2,2	2,5	3,2	2,1	1,1	0,6
	Chaetognatha	0,2	0,2	0,2	0,5	0,3	0,3	0,6	0,06	
	Polychaeta	0,01	0,01	0,02	0,01	0,03	0,03	0,01	0,04	0,02
	Pteropoda	0,4	0,2						0,03	0,02
	Euphausiacea	0,2		0,1				3,8		
	Siphonophora			0,05					1,3	
	Medusae				0,01					
	Pisces — larvae							0,03	0,01	
	Amphipoda	0,3								
		39	37	38	46	44	42	48	47	43
300—600	Copepoda	3.9	1.6	1.9	5.2	4.6	5.3	5.9	8.3	
	Chaetognatha	0,7	1,1	4,1	1,8	0,8	0,7	1,1	1,1	
	Polychaeta	0,01	0,03	0,02	0,01	0,02	0,02	0,03	0,02	
	Medusae	0,01		0,04	0,2	0,01			0,05	
	Euphausiacea	0,02	2,7		0,2					
	Siphonophora	0,3			4,7					
	Amphipoda	0,08								
	Pisces — larvae			0,01						
	Pteropoda				0,01	0,01				
		44	39	46	43	47				
>600 m	Copepoda	0,4	1,2	2,0	4,2	11,0				
	Chaetognatha	0,5	0,03	0,2	0,2	1,5				
	Polychaeta	0,01	0,02	0,01	0,3	0,01				
	Euphausiacea					1,0				
	Siphonophora		0,04	0,2		1,1				
	Pteropoda	0,01			0,03	0,01				
	Medusae					0,03				
	Pisces — larvae					0,1				
	Amphipoda				0,01					
	Mysidacea			0,06						

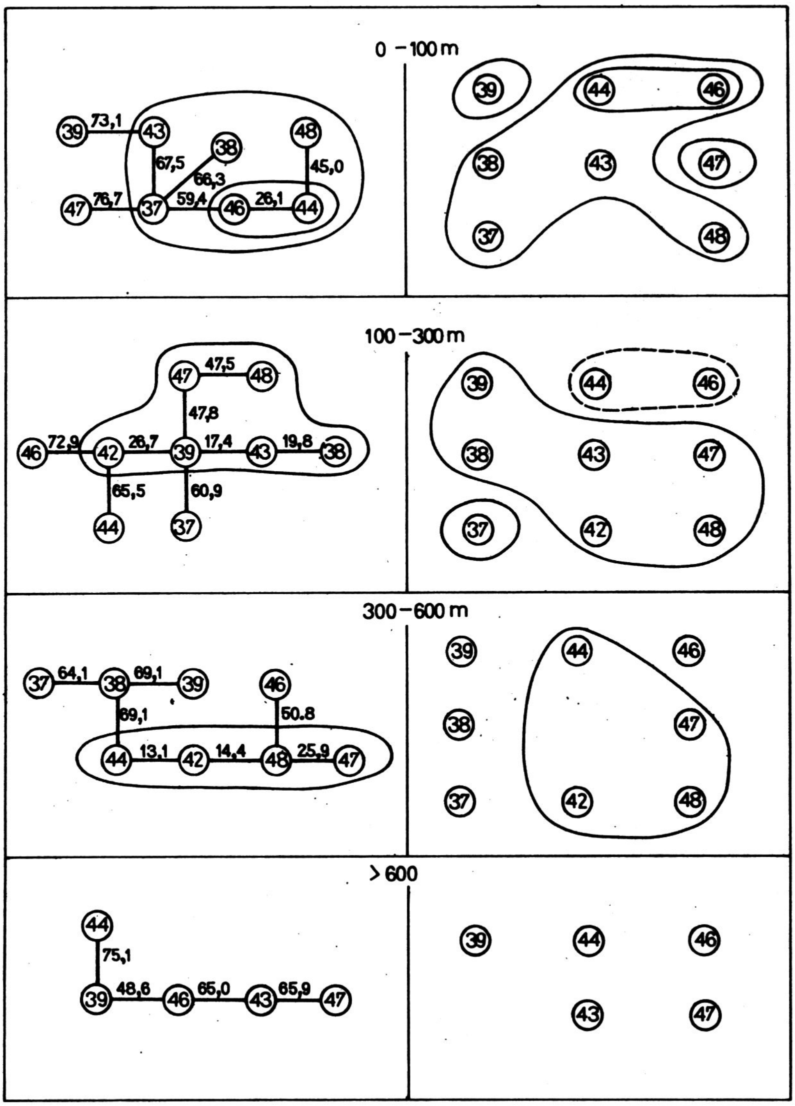

Fig. 2. The shortest dendrites of stations. Similarity in particular water layers with natural divisions of dendrites (left); groupings of stations corresponding to these divisions are presented to the right

nent were here copepods with a considerable share of Euphausiacea. The dendrite analysis of the similarity of particular stations in this water layer (Fig. 2) indicates to a high similarity of stations 44 and 46; on the other hand, at the weaker dendrite division stations 37, 38, 44, 46, 43 and 48 can be regarded as similar (in this analysis extremely high biomass of Salpae in station 37 was not considered). At any possible division there are distin-

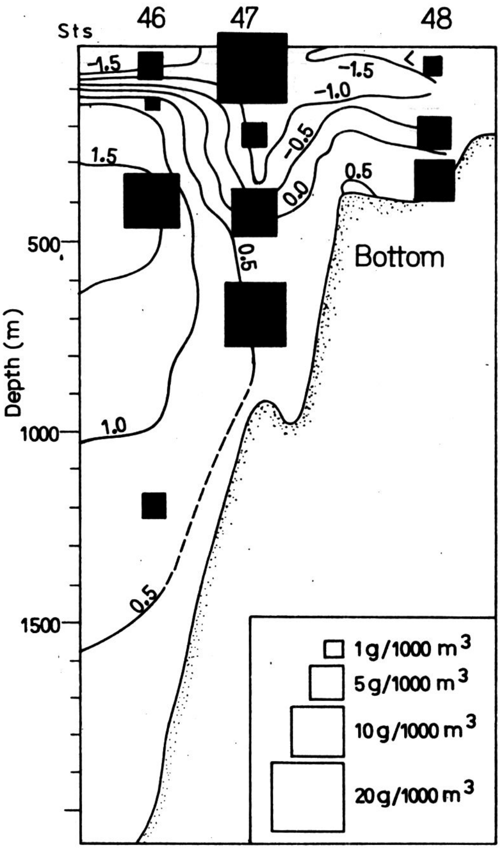

Fig. 3. Zooplankton biomass distribution at different depths in the transect I drawn according to Tab. 2. Squares corresponding to the biomass are drawn in the middle of particular vertical haul

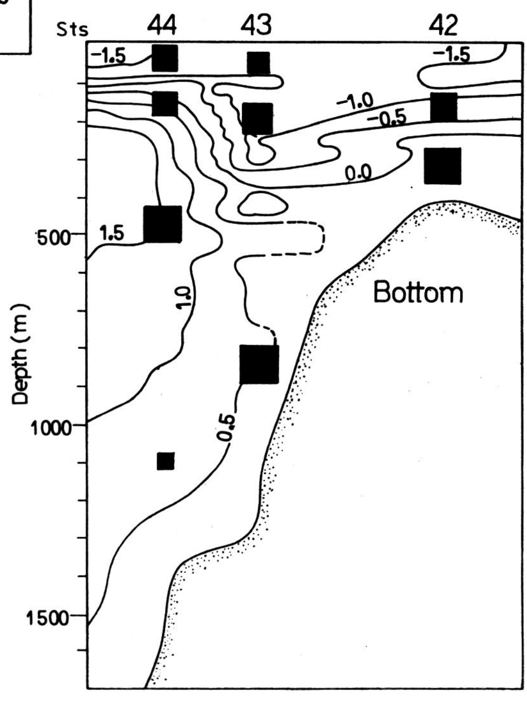

Fig. 4. Zooplankton biomass distribution at different depths in the transect II. Explanations as in Fig. 3

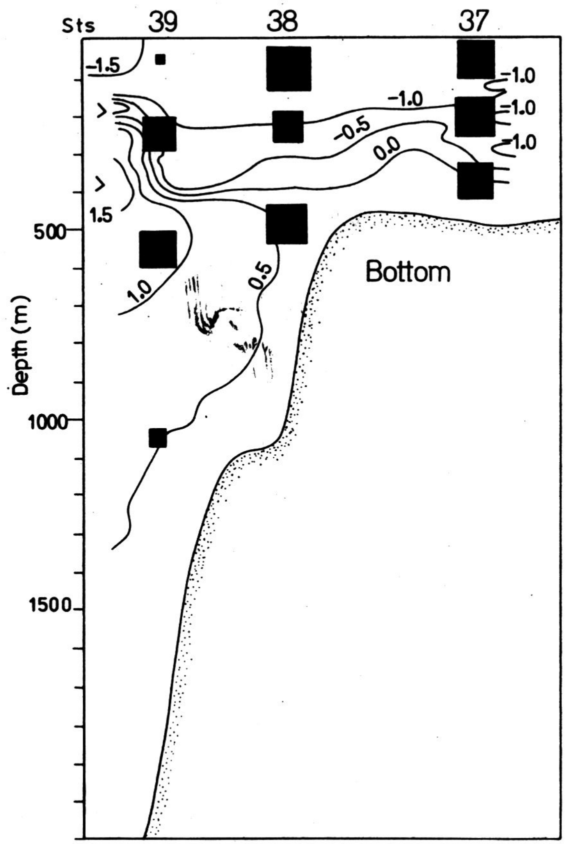

Fig. 5. Zooplankton biomass distributions at different depths in the transect III. Explanations as in Fig. 3

guished: station 39 by its extremely low biomass and general poverty of zooplankton as well as station 47 by its extremely high biomass value, especially of Copepoda; here only Chaetognatha were present in the uppermost layer, being usually characteristic of lower depths (their maximal biomass observed in the layer 300—600 m). Polychaeta, common and abundant in deeper layers, in the layer 0—100 m were observed only in stations 37 and 38, underlining therefore their similarity and distinctness from the other stations.

In the layer 100—300 m the biomass distribution was more balanced. The index of dispersion was here 50%. The constant elements of the assemblage were Copepoda, Chaetognatha and Polychaeta (Tab. 1). Dendrite analysis (Fig. 2) shows that stations 48, 47, 42, 39 43 and 38 form one group. Three remaining ones are different and each constitutes a cenological individuality: station 37 due to a comparatively high euphausiid biomass, station 44 because of high biomass of Siphonophora and station 46 due to the low biomass of total zooplankton. However there is some tendency indicating the similarity of the two latter stations 44 and 46 consisting in the distinctly lower biomass share of two leading groups — Copepoda and Chaetognatha. This similarity is indicated in Fig. 2 by the broken line.

The layer 300—600 m is an area of the highest zooplankton biomass concentration in the whole investigated water column (Tab. 2). Here, moreover, the lowest dispersion of biomass value was observed, amounting for this layer to 36.6%. With regard to the assemblage composition and biomass of particular taxa stations 44, 42, 48 and 47 constitute a group of high similarity. Four remaining stations are cenological individualities. The highest biomass value were noted in stations 46 and 47.

In the deepest investigated layer the distribution of biomass was very uneven. The index of dispersion amounted to 117% (Tab. 2). The biomass values were usually low, except the stations 43 and 47. In this last station the biomass amounted as much as nearly 15 g in 1000 m^3. It is worth mentioning that zooplankton composition was the richest in this very station.

The complicated water circulation caused in this area a very uneven distribution of zooplankton in the region under study. However an attempt is justified to estimate the average zooplankton biomass in the analyzed water mass. For all 30 zooplankton samples the mean amounted to 4.96 g in 1000 m^3, whereas its 95% confidence limits were between 3.3 and 6.6 g in 1000 m^3.

Table 2

The distribution of the total zooplankton biomass in the investigated water column in g 1000 m^{-3}. Salpae and Ctenophora are not included.

Depth	Station									$\bar{x} \pm SD$	$V = \frac{SD}{\bar{x}} \times 100$
	37	38	39	42	43	44	48	47	46		
0—100 m	4,9	7,8	0,4	—	1,6	1,9	1,1	20,3	2,0	5,0±6,6	132%
100—300 m	6,5	3,6	2,7	2,7	2,8	2,6	4,4	2,6	0,6	3,2±1,6	50%
300—600 m	5,5	6,0	5,0	6,0	—	5,4	7,0	9,5	12,2	7,1±2,6	36,6%
>600 m			1,2		4,7	0,9		14,5	2,5	4,8±5,6	116,7%

4. Discussion

The presence of the hydrological front in the investigated area as well as the period of study (austral spring) undoubtedly influenced the distribution, structure and biomass of zooplankton. Our results indicate that the studied area can be divided into two parts. In the layers 0—100 and 100—300 m the stations 44 and 46 seem to form a uniform unity different from the remaining stations. This situation suggests that between stations 44 and 46, and stations 39, 43 and 47 the hydrological front runs. This is concordant with the course of the frontal line presented by Rakusa-Susz-

Table 3

The biomass of the identified taxa (mg 1000 m^{-3}) at the particular stations and water layers. Explanations: ● — refers to Foraminifera and Ostracoda which were weighed together with Copepoda; the biomass of Foraminifera and Ostracoda was insignificant.

(a) Station No	48			47				46				42		43			44				37			38			39			
(b) Sounding (m)	420			900				1900				400		1300			1600				500			700			1500			
(c) Haul depth (m)	0—100	100—300	300—400	0—100	100—350	350—500	500—880	0—75	75—200	200—600	600—1800	100—250	250—400	0—100	100—300	500—1200	0—75	75—250	250—700	700—1500	0—100	100—300	300—450	0—150	150—300	300—680	0—100	100—400	400—700	700—1400
(d) Filtrated water wolume	40	80	40	40	100	60	152	30	50	160	480	60	60	40	80	280	30	70	180	320	40	80	60	60	60	152	40	120	120	280
(e) Total wet weight (mg 1000 m^{-3})	1050	8013	6975	20280	4305	9506	15685	2000	640	12171	2495	2716	12350	1550	2801	5992	1932	2563	5442	909	43825	6502	5511	7850	3599	6102	420	2665	5048	1242
Taxon																														
1. Foraminifera		●			●	●	●				●										●			●		●				
2. Hydrozoa — medusae						50	30			212									4							40		8	8	
3. Ctenophora													6400																	
4. Siphonophora							1079			4675	173	50					266	1285											333	43
5. Polychaeta		12,5	·25		10	17	7		20	6	4	17	17		33	263		43	17	13	25	2	33	17	33	18		8	8	21
6. *Pelagobia longicirrata*		+	+		+	+	+		+	+	+	+	+		+	+		+	+	+	+	+	+	+	+	+		+	+	+
7. *Typhloscolex mülleri*			+									+				+			+			+	+		+				+	
8. *Tomopteris planktonis*							+				+				+			+												
9. Tomopteris carpenteri					+										+	+		+												
10. *Tomopteris* spp.										+		+				+			+							+				
11. Spionidae gen. sp. juv.															+			+	+	+										
12. Pteropoda		350			150		6		20	6						34		28	5	9							20			
13. Ostracoda						●	●		●	●						●			●	●								●		
14. Copepoda	1050	3450	5900	18325	2220	8333	10802	1800	600	5187	2047	1933	5266	550	2500	4188	1666	1143	4583	406	3100	2100	1627	7800	3233	1889	25	2183	3933	1150
15. Amphipoda		275														14													83	
16. Euphausiacea		150		1550			973	200		175		133		1000							1800	3775	2722	33			375		16	
17. *Euphausia superba*				+				+																						
18. *E. superba* — furcilia VI												+		+													+		+	
19. *E. crystallorophias*																					+									
20. *E. frigida*							+																							
21. *Thysanoessa macrura*		+		+			+			+				+							+	+	+	+						
22. *T. macrura* — nauplii			+			+	+			+			+																	
23. *T. macrura* – *metanauplii*						+	+			+			+										+							
24. *T. macrura* — calyptopis I		+	+		+	+	+		+	+		+	+		+			+	+	+	+	+		+	+	+		+	+	
25. *T. macrura* — calyptopis II																					+			+	+					
26. Euphausiacea — eggs		+	+			+	+	+	+	+		+	+			+		+	+	+		+	+		+	+		+	+	
27. Mysidacea											63																			
28. Decapoda — larvae					5																									
29. Chaetognatha		150	1050	25	230	1106	1539			1812	208	233	667		262	160		57	833	481		600	1129		333	4141		466	667	28
30. *Eukrohnia hamata*		+	+	+	+	+	+			+	+		+		+	+			+	+		+	+		+	+		+	+	
32. *Eukrohnia bathypelagica*							+				+				+	+				+									+	+
32. *Eukrohnia fowleri*											+		+							+										
33. *Eukrohnia bathyantarctica*																				+										
34. *Eukrohnia* sp.		+	+		+		+			+	+	+	+		+	+		+		+					+	+		+	+	+
35. *Sagitta gazellae*							+					+										+				+				
36. *Sagitta macrocephala*																+			+											
37. *Sagitta marri*			+		+		+																							
38. Sagitta maxima					+		+			+		+							+											
39. Salpae		3625			1690		1144									1333					38900									
40. Pisces — larvae							105								6			7				25				7				
41. Indef.				380						98		350														7				

czewski (1988b; Fig. 1), established after the analysis of physico-chemical parameters. Nast (1986), who investigated zooplankton in the same region, has found differences in the abundance of *Euphausia superba* and Salpae between two sides of the Scotia Front, a northern limit of the Weddell-Scotia Confluence; this author underlined the role of the front as a biological border. Our results confirm this point of view. Similar results were obtained in detailed studies of some planktonic groups of this region (Kittel 1988 — Euphausiacea, Siciński 1988 — Polychaeta).

Interesting were the distributions of zooplankton in some of the stations. Stein (1986) was of the opinion that the influence of WSC can be observed in physico-chemical parameters as deep as more than 2000 m, however our results did not make apparent this influence in layers deeper than 300 m. In the depths 300—600 m and below the results are difficult for interpretation. The exception is the station 47; a very uncommon zooplankton biomass distribution was here observed in the vertical cross-section with maxima in the uppermost layer caused by the upwelling and in the deepest layer caused by the downwelling (Grelowski and Wojewódzki 1988; Rakusa-Suszczewski 1988b).

The biomass of the Antarctic zooplankton of the epipelagic zone varies significantly in the yearly cycle (Foxton 1956; Everson 1977; Voronina 1984), depending in general on the phytoplankton productivity (Foxton 1956). Vertical distribution of zooplankton is also dependent on the phytoplankton. In winter the phytoplankton productivity is very low and zooplankton occurs deeper. During the austral summer the biomass of zooplankton in the epipelagic zone increases significantly (Foxton 1956; Everson 1977). The majority of data on the biomass of the Southern Ocean zooplankton came from the summer period. Some of the earliest estimates for the whole Antarctica are due to Foxton (1956). In the layer 0—250 m in December this author observed the mean zooplankton volume amounting to 43.8 $mm^3\ m^{-3}$ (corresponding to abt. 44 g in 1000 m^3), in January — 30.7 $mm^3\ m^{-3}$ (abt. 31 g in 1000 m^3) and in February — 45 $mm^3\ m^{-3}$ (abt. 45 g in 1000 m^3). According to Voronina and Naumov (1968) the mean summer zooplankton biomass in the Indian Sector of the Southern Ocean amounted to 72.5 $mg\ m^{-3}$ (72.5 g per 1000 m^3) and 74.6 $mg\ m^{-3}$ (74.6 g per 1000 m^3) in the Pacific Sector.

The biomass of summer zooplankton in the Drake Passage, in the Bransfield Strait and in neighbouring areas was recently studied within the framework of the BIOMASS program. Mujica and Torres (1982) studied the layer 0—200 m in December and January and they observed the amounts of zooplankton varying between 50 and 200 ml per 1000 m^3 (corresponding to abt. 50—200 g per 1000 m^3), with maximal values found in the vicinity of Elephant Island (Piloto Pardo Is.).

Zooplankton studies of Jażdżewski, Kittel and Łotocki (1982) were carried out in February and March. The total plankton amount observed by these authors in the Bransfield Strait in the layer 0—100 m on average amounted to 96 $mm^3\ m^{-3}$ (corresponding to abt. 96 g per 1000 m^3) and in the layer 100—300 m the mean was 31 $mm^3\ m^{-3}$ (abt. 31 g per 1000 m^3). In the Drake Passage the corresponding amounts were 458 $m^3\ m^{-3}$ (abt. 458 g per 1000 m^3) and 19 $mm^3\ m^{-3}$ (abt. 19 g per 1000 m^3).

Witek et al. (1985) for similar area and the area of South Orkneys have found in December and January the mean zooplankton biomass amounting to 320 ml (abt. 320 g) per 1000 m^3. However without Salpae and large euphausiids caught sometimes in masses by the Bongo-net used by these authors the zooplankton biomass amounted only to abt. 24 g per 1000 m^3.

Comparatively few biomass estimates of epipelagic zooplankton are available from the austral spring (October—November). We know however that this biomass is low and amounts to abt. 10 g per 1000 m^3 (Foxton 1956; Everson 1977; Fukuchi, Tanimura and Ohtsuka 1985; Kawamura 1986; Yamada and Kawamura 1986). At the same time the bulk of zooplankton is then distributed below 250 m (Foxton 1956).

In the present study carried out also in the austral spring we have observed similar regularities. The mean zooplankton biomass of the whole water column studied was low and amounted only to 5 g per 1000 m^3; the maximal values (on the average abt. 7 g per 1000 m^3) were observed in the layer 300—600 m.

A very complicated hydrological situation occurring in the investigated region caused a considerable variability of the biomass values in particular stations. Stations 39, 44 and 46 were similar in respect to their low total biomass values in contrast to the pair of stations — 43 and 47 which were characterized by comparatively high biomass values and a rather complicated structure of zooplankton assemblage. The reason of such zooplankton distribution is most probably the run of the Scotia Front line dividing, especially in surface layers, the studied area in two parts. This line runs between stations 46 and 47, 44 and 43, and north of station 39 (Fig. 1).

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6. Streszczenie

Badano kolumnę wody będącą pod wpływem Frontu Scotia — północnej granicy konfluencji Weddell-Scotia (rys. 1).

Zgrupowanie zooplanktonu badanego obszaru zdominowane jest przez Copepoda. Obok nich pospolitymi taksonami okazały się Chaetognatha, Polychaeta, Euphausiacea oraz Pteropoda i one też w zasadzie decydowały o biomasie zooplanktonu (app., tab. 1 i 2).

W oparciu o analizę podobieństw stacji pod względem składu zooplanktonu i rozkładu biomasy między poszczególnymi taksonami (rys. 2) stwierdzono, że badany akwen dzieli się na dwa obszary, co szczególnie wyraźnie widać w warstwach płytszych, tj. 0—100 i 100—300 m. Tam też, na podstawie analiz fizyko-chemicznych stwierdzono strefę frontalną.

Pionowe ruchy wód w badanym akwenie decydują o dość specyficznym rozkładzie pionowym biomasy. Zooplankton zgrupowany jest generalnie w warstwach głębszych (rys. 3, 4, 5). Średnia biomasa planktonu była niewielka, wynosiła bowiem 5 g 1000^{-3} wody.