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Population Structure of Krill (*Euphausia superba* Dana) Near Sea-Ice Zone Between Elephant Island and South Orkney Islands (December 1988—January 1989)

Wojciech Kittel and Jacek Sicinski

Laboratory of Polar Biology, Department of Invertebrate Zoology and Hydrobiology, Institute of Environmental Biology, University of Lodz, Banacha Str. 12/16, 90—237 Lodz, Poland

Abstract : The effect of the sea-ice zone on the abundance, distribution and population structure of krill in three regions has been investigated : near Elephant Island, near South Orkney Islands and in the region in between. Based on the analysis of krill population structure these three regions can be clearly distinguished. Mature krill was dominant in the Elephant Island region and the South Orkney Islands region. In the Middle region krill were smaller and juvenile individuals dominated in the population. In this very region small but statistically significant differences in mean krill body length between the populations of the open ocean and of the pack-ice were observed.

Key words : antarctic, krill, sea-ice zone

Introduction

Antarctic sea-ice forms a peculiar ecosystem. It is an environment of rich development of the epontic flora and fauna. Immediately below the ice surface a rich community of consumers occurs, consisting mainly of Amphipoda and Euphausiacea that are the food of secondary consumers - fishes, penguins, seals and whales (Rakusa-Suszczewski, 1989). Productivity of this ecosystem is very high. Ligowski et al. (1988) recorded 700 times higher amounts of diatoms and chlorophyll content in the pack-ice in the surrounding sea water. The amount of bacteria can be also 1000 times higher in the ice than in the sea water (Zdanowski, 1988). Sea-ice influences physical, chemical and hydrodynamic processes occurring in the water column below and in its neighbourhood.

Presently several scientific programs are focussing on these problems ; as most important can be mentioned ASIZ (SCAR), AMERIEZ (USA), and EPOS (Germany). In the framework of such programs some papers have been published concerning the distribution of zooplankton in the ice edge zone (Hopkins and Torres, 1988; Lancraft et al., 1989; Cuzin-Roudy, and Schalk, 1989), the distribution and behavior of krill (O'Brien, 1987; Daly and Macaulay, 1988; Marschall, 1988) or the diet of zooplankton including krill (Hopkins and Torres, 1989).

In the break of 1988 and 1989 (December —January) the Polish Academy of Sciences has organized an Antarctic Expedition (Sea-Ice-Zone: SIZ) which investigated the region of northern Weddell Sea between Elephant Island and South Orkney Islands. Quite preliminary general results of these investigations were published by Rakusa-Suszczewski (1989).

The results presented below concern only the distribution of krill(*Euphausia superba*) in the investigated region.

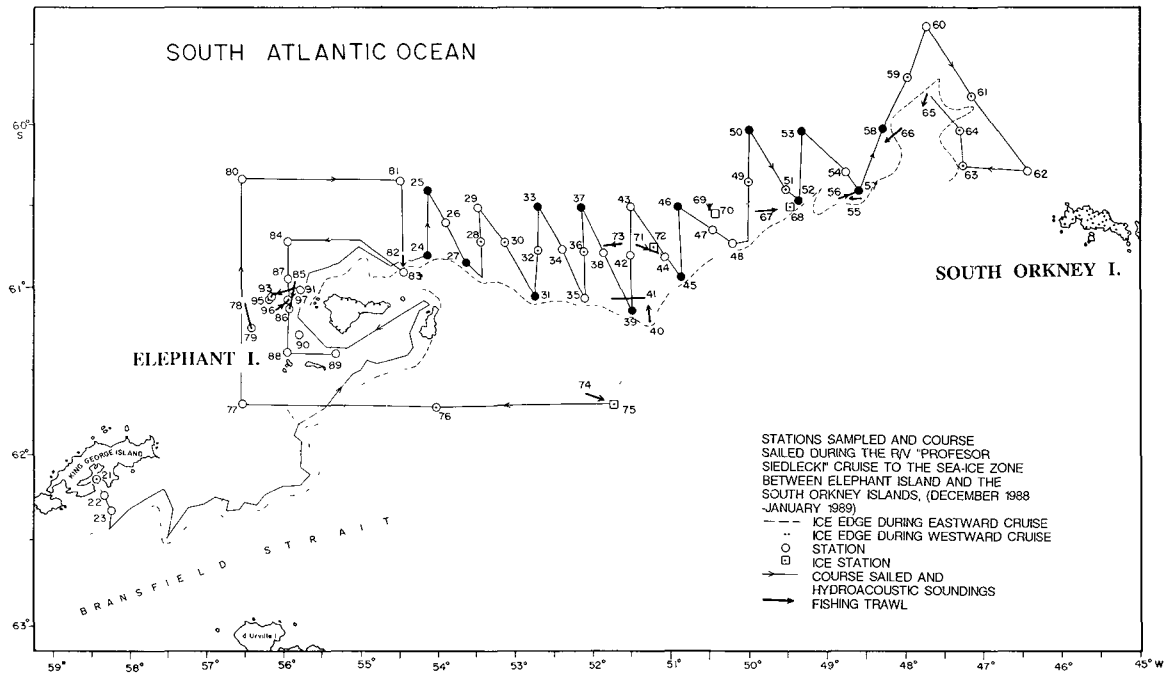

Fig. 1. Distribution of krill samples (black dots) during R/V "*Profesor Siedlecki*" cruise, December 1988–January 1989.

Material and Methods

Planktonic samples were collected using a Bongo net at 14 stations from the board of R/V "*Profesor Siedlecki*" (Fig. 1). The Bongo net rings were 60 cm in diameter and both rings were supplied with a gauze 0.333 mm mesh.

Trawlings were double oblique, from the surface down to about 200 m and then hauled up at a speed of about 3 knots. The amount of filtrated water was calculated using a flowmeter. The present paper is based on samples collected by a single net.

One hundred random individuals of krill from each sample were chosen and analysed. Body length was measured from the tip of the rostrum to the end of the telson and sexual development stages were determined on the basis of external sexual characters (Dzik, and Jazdzewski, 1978; Wolnomiejski et al., 1980). The following stages were distinguished: 1-juveniles, 2-subadult males, 3-adult males, 4-subadult females, 5-adult females, 6-adult females with eggs, 7-spent females. These stages were segregated into three groups of sexual maturity : juvenile krill –stage 1, immature krill–stages 2 and 4, and mature krill–stages 3, 5, 6 and 7 (see Table 2).

The degree of gut filling was determined using a 5–grade scale (Wolnomiejski et al., 1980).

Hydrography

Tokarczyk et al., (in press) presented the description of water masses distribution in the survey area. Based on the analysis of temperature, salinity, silicates, nitrates and

chlorophyll content these authors distinguished four types of water masses.

The western part was occupied by surface waters of the Bellingshausen Sea flowing through the Drake Passage and Bransfield Strait (Figs. 2 and 3). This water layer, about 150 m thick, had relatively high temperatures (+0.4° to +0.8℃) and its salinity was about 34.0 ‰ (Fig. 4).

Below these waters, down about 150–200 m, Circumpolar Warm Deep Waters with a temperature of about +1.8℃ and salinity of 34.6 ‰ were found (Figs. 3, 5 and 7). The eastern boundary of these two masses shows the position of Weddell-Scotia Confluence.

The central and eastern parts were occupied by surface waters of Weddell Sea (Figs. 1 and 2). In the eastern part of the study region near South Orkney Islands, a thin water layer (about 50 m) was distinctly warmer (0° to +0.6℃) and of less salinity (33.4 to 33.8 ‰). It is due to the summer modification of Weddell Sea surface water (Figs. 3, 4 and 6). Below a depth of about 50 m temperature and salinity is typical for cold waters of the central part of the study region (Figs. 3, 5 and 7). According to these authors these waters are relatively homogenous surface waters of winter modification.

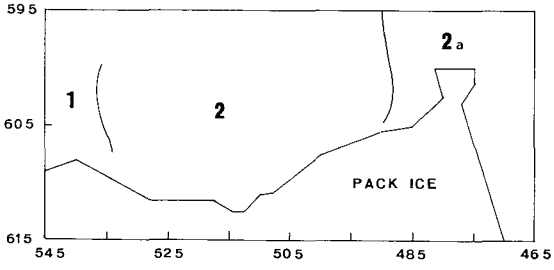

Fig. 2. Distribution of surface water masses (according to Tokarczyk et al., in press). 1—Antarctic Surface Water flowing from the Drake Passage and Bransfield Strait, 2—Weddell Sea Surface Water (winter modification). 2a—Weddell Sea Surface Water (summer modification).

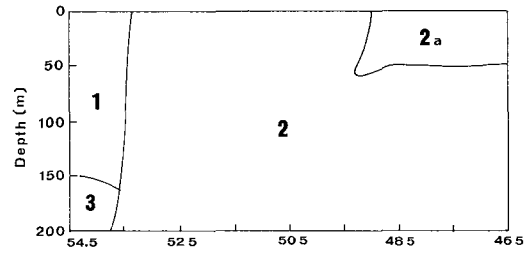

Fig. 3. Vertical distribution of water masses (according to Tokarczyk et al., in press). 1—Antarctic Surface Water flowing from the Drake Passage and Bransfield Strait, 2—Weddell Sea Surface Water (winter modification), 2a—Weddell Sea Surface Water (summer modification), 3—Circumpolar Warm Deep Waters (CWDW).

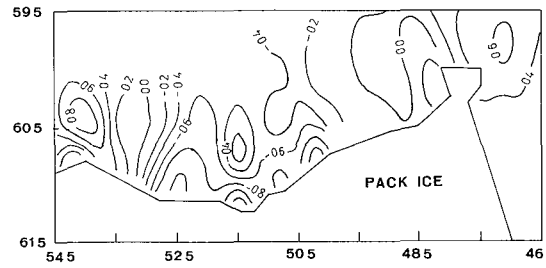

Fig. 4. Surface distribution of temperature (according to Tokarczyk et al., in press).

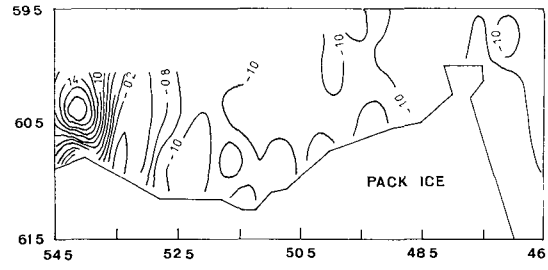

Fig. 5. Horizontal distribution of temperature at 200 m depth (according to Tokarczyk et al., in press).

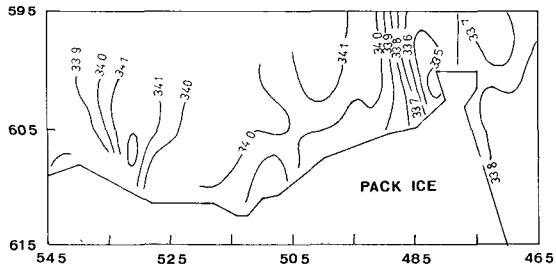

Fig. 6. Surface distribution of salinity (according to Tokarczyk et al., in press).

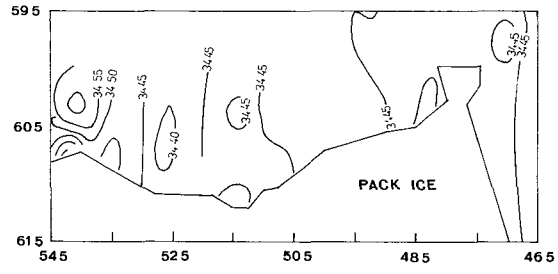

Fig. 7. Horizontal distribution of salinity at 200m depth(according to Tokarczyk et al., in press).

Results

In macroplankton of the pack-ice zone between Elephant Island and the South Orkney Islands three euphausiid species were recorded. They were : *Euphausia superba*, *E. frigida* and *Thysanoessa macrura*. Two of them, *E. superba* and *E. frigida*, clearly dominated (Table 1). Presented data concern only *E.* superba.

On the basis of analysis of krill population three regions can be clearly distinguished (Tables 2 and 3, Fig. 8).

1. Elephant Island region

Mean body length of krill here was 40.3 mm, and in the population sexually mature individuals dominated, amounting to 55.5 % (Table 3, Fig. 8).

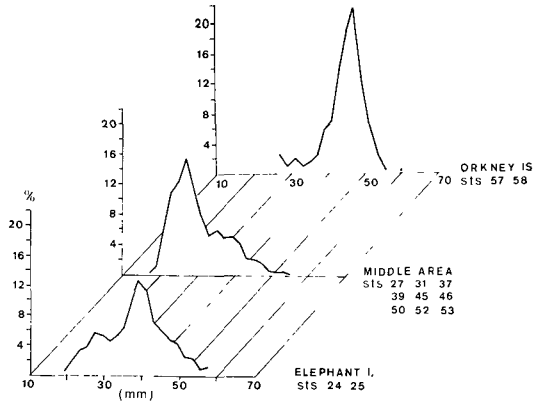

Fig. 8. Population structure of krill in three distinguished regions.

2. Middle region

Krill were smaller here, with mean body length of 31.9 mm, and juvenile individuals dominated with a share of 50 % (Table 3, Fig. 8).

3. South Orkney Islands region

Krill mean body length was 41.2 mm and sexually mature individuals clearly dominated, amounting to 72.5 % (Table 3, Fig. 8).

On the basis of hydrological investigations (Figs. 2—7) the most homogeneous waters occurred in the central part of the investigation area—middle region.

In the middle region (st. 27, 31, 33, 37, 39, 45, 46, 50, 52, 53) small but statistically significant differences in mean body length between the populations of the open ocean and those of the pack-ice zone were observed (33.4 mm and 30.4 mm), respectively (Fig. 9). The share of particular maturity groups was also somewhat different. In the waters of the open ocean the percentage of sexually mature krill was higher by 10 % (Table 4, Fig. 10).

Table 1. Percentage contribution of *E. superba*, *E. frigida* and *Th. macrura* in the samples.

Station No.	24	25	27	31	33	37	39	45	46	50	52	53	57	58
E. superba	44.9	27.4	43.0	45.9	42.9	4.6	100	24.7	59.8	53.9	60.4	55.2	39.3	36.8
E. frigida					0.8	0.3			1.8	0.2				
Th. macrura	55.0	71.7	56.9	54.0	56.3	95.0		75.3	38.4	45.8	39.6	44.8	60.6	63.2
Total ind/1000m^2	403	113	216	211	254	606	100	299	336	399	603	427	127	247

Table 2. Biological characteristics of krill catches during the Sea−Ice Zone expedition (Dec. 1988−Jan. 1989)

Research area		Elephant I.		Middle area										Orkney Is.	
Station No.		24	25	27	31	33	37	39	45	46	50	52	55	57	58
Depth of bottom(m)		1160	3000	650	1050	550	602	1052	1150	1950	3150	1520	3240	1900	3850
Depth of trawling(m)		200	200	200	200	200	200	200	200	200	200	200	200	200	200
Average length(mm)		39.4	41.2	33.4	31.5	35.7	36.6	28.7	25.5	33.2	32.5	33.1	28.9	45.3	44.3
Alimentary tract filling		3.7	4.02	3.8	3.9	3.5	3.5	3.9	4.3	4.3	3.5	2.3	4.0	3.7	4.0
Number of analysed specimens		100	100	100	100	100	100	100	100	100	100	100	100	100	100
Percent contribution of development stages and mean size of krill															
1. juvenes	%	13	7	43	45	27	19	62	85	40	51	50	73	−	8
	m	24.5	24.1	25.2	26.0	26.1	25.7	25.5	23.7	26.5	28.1	26.4	26.6	−	29.0
2. subadult males	%	28	23	23	17	22	25	17	10	36	36	17	15	26	21
	m	40.0	36.6	35.9	35.9	35.6	37.9	33.7	34.4	34.9	35.1	37.9	34.3	43.7	40.4
3. adult males	%	17	34	7	2	9	12	2	1	4	2	5	5	24	26
	m	48.6	49.0	47.7	43.0	46.7	44.8	43.0	44.0	51.7	51.0	46.0	45.2	47.7	48.9
4. subadult	%	11	7	10	22	4	10	14	3	6	−	4	1	−	−
females	m	32.0	33.7	33.0	33.2	36.0	31.1	31.8	35.0	34.5	−	33.3	29.0	−	−
5. adult femalse	%	23	26	9	14	33	34	5	1	14	11	24	1	44	25
	m	41.7	41.0	41.2	39.4	39.0	40.1	38.2	37.0	40.7	41.5	40.8	46.0	45.5	44.2
6. adult females	%	7	3	8	−	1	−	−	−	−	−	−	−	6	−
with eggs	m	44.4	46.0	44.7	−	52.0	−	−	−	−	−	−	−	48.5	−
7. spend females	%	1	−	−	−	4	−	−	−	−	−	−	−	−	−
	m	49.0	−	−	−	45.6	−	−	−	−	−	−	−	−	48.7
Immature krill total	%	39	30	33	39	26	35	31	13	52	36	21	16	26	21
	m	37.6	36.0	35.0	34.4	35.6	36.0	32.8	34.5	34.9	35.1	37.0	34.0	43.7	39.9
Mature krill total	%	48	63	24	16	47	46	7	2	18	13	29	6	74	71
	m	44.7	45.6	44.3	39.8	41.3	41.6	39.6	40.5	43.0	42.9	41.7	45.3	45.9	47.2

Table 3. Percentage contribution of *Euphausia superba* developement groups in distinguished regions.

Region	Elephant	Middle	Orkney
Juvenile krill	10.0	50.0	4.0
Immature krill	34.5	30.2	23.5
Mature krill	55.5	20.8	72.5

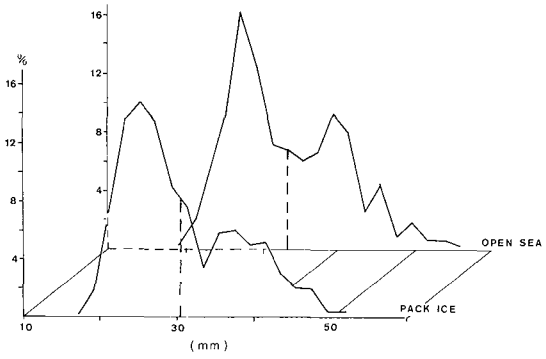

Fig. 9. Population structure of krill in the waters of the open ocean and those of the pack-ice zone (Middle region only).

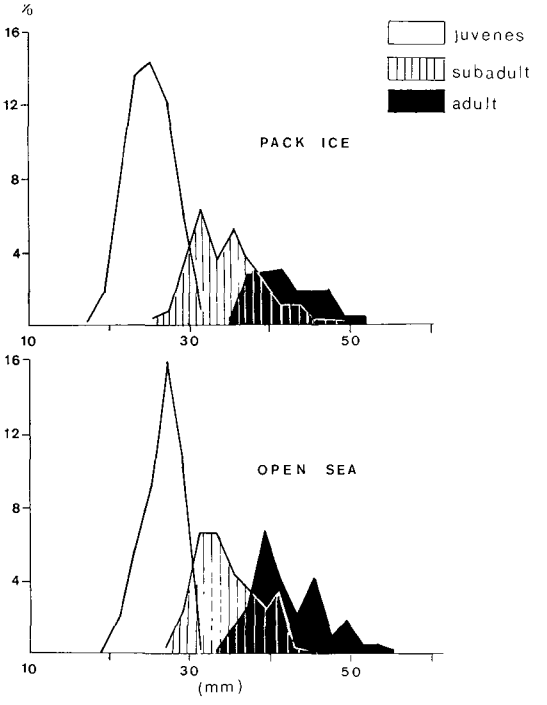

Fig.10. Krill body length spectrum of three sexual maturity groups in waters of the open ocean and those of the pack-ice zone (Middle region only).

Table 4. Percentage contribution of development groups in the pack ice zone and in the open sea on the Middle region

Region	Pack ice	Open sea
Juvenile krill	57.0	42.0
Immature krill	27.4	31.6
Mature krill	15.6	26.4

Discussion

Our results, preliminary as they are, correspond well with the results of ealier investigations. The presence of three regions clearly differing in the population structure of *E. superba* can be explained by krill behaviour and physiology.

Tokarczyk et al., (in press) have noted during our cruise significantly higher water temperatures in the regions of Elephant Island and South Orkney Islands than in the middle region.

According to Daly and Macaulay (1988) the occurrence of positive water temperature in the neighbourhood of pack-ice induce the leaving of krill of its winter habitat, which is pack-ice. In warmer waters the respiratory enzymes activity increases (Cuzin-Roudy and Schalk, 1989). This is connected with the increases of sexual activity and probably with partial change of the diet.

Hopkins and Torres (1989) observed that krill occurring below the pack-ice feed on diatoms, Copepoda and Tintinnidae whereas in open sea-mainly on diatoms. These data concerned mainly the subadult and adult krill and such stages were caught in these two (Elephant Island and Orkney Islands) regions.

In the Middle region that was totally influenced by cold Weddell Sea waters with negative temperatures, krill populations consisted mainly of small animals, and juvenile forms clearly dominated, especially in the stations close to the pack-ice. Similar observations were noted by Cadee et al. (1989); these authors also recorded young stages and immature krill below the pack-ice and its aggregations were small. In the open waters of the area of their studies krill were generally larger in size and the share of adult forms was higher. The results obtained by Cuzin-Roudy and Schalk (1989) showed similar krill population structure in open Antarctic water outside the pack-ice area.

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