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Distribution of bacteria, organic carbon and amino acids in the southern part of Drake Passage and in Bransfield Strait during the BIOMASS-SIBEX (December 1983 — January 1984*)

ABSTRACT: Water samples were collected at 12 oceanographic stations from six standard depths ranging from 0 to 100 and 150 m. The number of bacteria and concentration of organic components were expressed in adequate units per 1 litre of sea water and in the form of the integrated values for the whole water column under 1 m^2 of sea of organic components were expressed in adequate units per 1 litre of sea water and in the form of the integrated values for the whole water column under 1 m^2 of sea surface. Total numbers of bacteria (TC) ranged from 0.16 to $7.31 \cdot 10^7$/l and 1.74 — — $5.67 \cdot 10^{12}/m^2$ saprophytic bacteria (CFU) 0.10 — 46.85 10^3/l and 0.62 — $27.7 \cdot 10^8/m^2$. contents of particulate organic carbon (POC) 0.02 — 0.25 mg/l and 3.5 — 20.0 g/m^2 dissolved organic carbon (DOC) 0.07 — 3.02 mg/l and 53.5 — 207.9 g/m^2, dissolved free amino acids (DFAA) 0 — 1.8965 µmol/l and 2.7 — 151.5 mmol/m^2, dissolved combined amino acids (DCAA) 0 — 2.9366 µmol/l and 16.5 — 163.5 mmol/m^2, particulate combined amino acids (PCAA) 0 — 3.0215 µmol/l and 3.7 — 249.0 mmol/m^2. Total numbers of bacteria and POC, DOC and DCAA concentrations, widely differentiated in the investigated area, were on the average much lower than the values obtaine in previous years. The saprophytic bacteria content and DFAA and PCAA concentrations were at a similar level to that in the past years. Higher TC and CFU values were observed in the areas with high concentrations of phytotoplankton to the NW of Anvers I. and around Clarence I.

Key words: Antarctic, bacteria, organic carbon, amino acids, distribution

1. Introduction

Heterotrophic bacteria play an immense role in utilization of organic matter in the marine ecosystems (Wood 1967). The dominant form of organic matter is dissolved organic matter (DOM) produced above all by decomposition of plant and animal detrital particles (Zdanowski 1980, Zdanowski unpubl., Jørgensen 1982, Goving and Silver 1983) and in

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result of metabolic excretion of the cellular products of phytoplankton (Lancelot 1979, Bell 1983). The essential feature of free heterotrophic bacteria is their ability to utilize dissolved organic matter in the widest spectrum range of the concentrations occurring in the natural environment and first and foremost their capacity for the uptake of low-molecular and high-molecular (e.g. soluble proteins) soluble compounds in concentrations in the range of $10^{-8} - 10^{-10}$ mol (Hoppe 1978, Hanson and Lowery 1983, Hollibaugh and Azam 1983).

Another bacterial group of major importance are bacteria utilizing particulate organic matter in pelagic waters. This matter is composed of detrital remains of plant origin occurring in large quantities in the coastal zones of the Antarctic waters (Zieliński 1981) as well as of animal detritus (Zdanowski 1981, Rakusa-Suszczewski and Zdanowski 1980, and fecal pellet (Gowing and Silver 1983). These bacteria, among which saprophytic bacteria (growing on nutrient agar) can be discerned (Zdanowski 1982), show a remarkably high degree of activity necessary for a quick decomposition of particulate organic matter and consequently for regeneration of all organic matter in the pelagic zone (Mc Cave 1975, Knauer and Martin 1981, in: Gowing and Silver 1983).

It is not quite clear how an accumulation of organic matter in the ecosystem affects the standing stock and activity of bacteria. First of all, we do not know much about natural concentration of the compounds accessible to bacteria and the distribution of bacteria throughout marine environments of the Antarctic. In the Drake Passage and Bransfield Strait regions, covered by the SIBEX research programme, studies on the distribution of bacteria and of organic compounds and on heterotrophic utilization of those compounds were carried out by Zdanowski (1982), Mężykowski (1982), and Bölter and Dawson (1982).

The aim of the present study, which is a continuation of investigations started during the FIBEX research programme, was to demonstrate the spatial distribution of free bacteria in relation to the distribution of organic components of the environment (DOC, POC, DFAA, DCAA and PCAA), and the determine whether there are any correlations between them.

2. Material and methods

Investigations were carried out in the region of Drake Passage along the northern shores of the South Shetland Islands and in Bransfield Strait from Anvers Island to the meridian of 54°W (Fig. 1). Detailed data on lacalization of the oceanographic stations in the area covered by the SIBEX programme are given by Rakusa-Suszczewski and Lipski

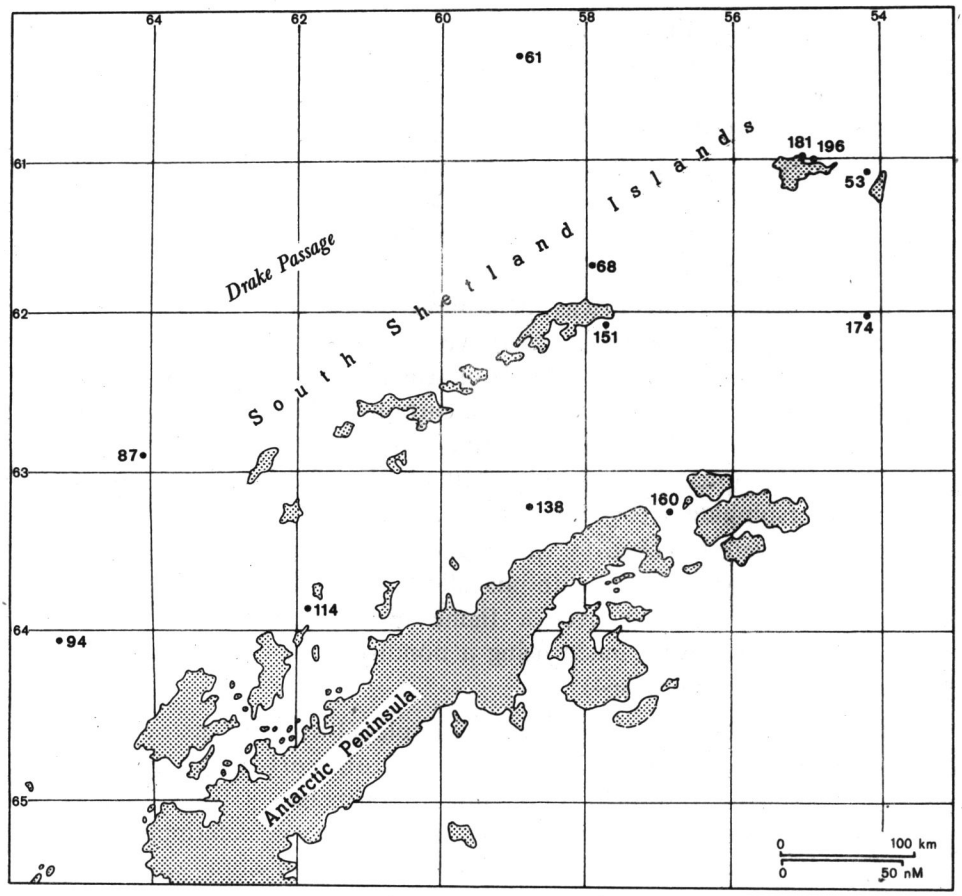

Fig. 1. Localization of the sampling stations (selected for the present studies) during BIOMASS-SIBEX

(1985). Twelve stations were selected for the studies on the distribution of bacteria . Determinations of DFAA were made at 11 stations determinations of other components at 7 stations, only . Investigations were conducted on board of the r/v "Profesor Siedlecki" between 21 December 1983 and 5 January 1984. Water samples were collected with a Van Dorn-type six-litre bottle, ethanol-sterilized (Kriss, Misustina and Lebedova 1969), at the depths of 0, 10, 30, 50, 100 and 150 m and exceptionally at the depths of 75, 80 and 90 m.

Saprophytic bacteria were determined in 50 ml sea-water samples as the colony forming units (CFU) on Millipore 47 mm HA membrane filters (pore size 0.22 μm). The tests were made in duplicate. The bacteria on filters were incubated at 9°C on nutrient agar (Zdanowski 1982).

The total number of bacteria (TC) was determined in 20 ml sea-water

samples, stabilized with formaldehyde (0.7% final concentration) with the epifluorescence microscopy method, using a Fluoval R2 microscope (Carl Zeiss — GDR). Bacteria settled on Nuclepore polycarbonate filters (pore size 0.20 μm), stained with acridine orange (Zimmermann and Meyer-Reil 1974), were counted in 10—40 microscopic fields (Cassel 1964). Confidence intervals were calculated at 95% level (Cavalli-Sforza and Lorenz 1972) and expressed in per cent of the mean values as a coefficient of variation. It ranged from 2 to 10%.

Organic carbon content was determined with the Menzel-Vaccaro method (1964) (Ławacz 1977). Dissolved organic carbon (DOC) content was detrmined in small samples (1 ml) of seawater passed through Whatman GF/C glass-fiber filters. Particulate organic carbon (POC) content was detrmined in the material settle on the glass -fibre filters after filtration of 100 ml of seawater. Samples in ampoules (10 ml) were mixed with 10 mg of potassium persulphate (recrystallized) and 0.2 ml of 6% phosphoric acid Traces of CO_2 were removed by flushing with nitrogen that was beforehand purified on a column filled with an alloy of KOH and absestos. Then the ampoules were sealed over a flame heated at 110°C for 2 hours and stored. Analyses were made using a nondispersive infrared gas analyzer (IRGA — Beckman mod. 864).

Amino acids were determined in water samples (1 ml) with the o-phthalaldehydefluorimetric method after Dawson and Liebezeit (1980). For fluorescence measurements a Spectro (Glo Filter Fluorimeter / Gilson Med. USA) was used. Dissolved free amino acids (DFAA) were determined directly in the non-filtered seawater samples. Dissolved combined amino acids (DCAA) were determined in water samples passed through glass-fiber filters (Whatman GF/C) after complete acid hydrolysis of DCAA into free amino acids (Bölter and Dawson 1982, Mężykowski 1982). The DCAA content was reckoned as a difference between the total content of amino acids in the filtered water sample and DFAA before hydrolysis. To find particulate combined amino acids (PCAA) the total amino acids were determined in non-filtered, acid hydrolyzed water samples. The PCAA were expressed as a difference between total amino acid content in the sample and the DCAA and DFAA contents.

The results obtained from all these analyses were reduced to adequate units per 1 l of seawater and integrated by the trapezium method for the water column from 0 to 150 m deep under 1 m^2 of the sea surface.

The evaluation of the organic carbon content in all the examined elements of the ecosystem had in view the presentation of the results in a uniform way, making possible direct comparison. As the basis for the calculations the following assumptions were set forth: for bacteria — average volume of a bacterial cell 0.179 μm^3 (Zdanowski — unpubl.), density of bacteria 1.1 g/cm^3

and carbon content in wet bacterial weight — 15% (Jørgenson 1982, Hagström et al. 1979); for amino acids — total nitrogen content — 16% is made up by alpha-amino nitrogen. In reality this percentage is lower due to the occurrence of amino acids containing other nitrogen groups in the amino acid mixture. Since the true composition of amino acids in sea water is not known therefore making any corrections would be unjustifiable.

3. Results

Saprophytic bacteria. The number of saprophytic bacteria in the present SIBEX research area averaged $4.8 \cdot 10^3$/l (Fig. 1, Table I) and was strongly differentiated ranging from 0.10 to $46.85 \cdot 10^3$/l. The total content of saprophytic bacteria in the 0—150 m water column under 1 m^2 of sea surface ranged from $0.62 \cdot 10^8/m^2$ (St. 68) up to $27.7 \cdot 10^8/m^2$ (St. 94). The largest quantities of saprophytic bacteria were recorded at two stations No. 94 to the NW of Anvers I. and No. 151 ($14.40 \cdot 10^8/m^2$) off the southern shores of King George I. At both stations the maximum GFU values were recorded at a depth of 10 m (46.85 and $46.25 \cdot 10^3$/l). The medium CFU values ($2.59 — 5.02 \cdot 10^8/m^2$) occurred in the region of Clarence I. and Elephant I. (Sts. 53, 181, 196), south of those islands, near 62°S (St. 171), and in the strait between Joinville I. and Antarctic Peninsula (St. 160). Low CFU values ($1.50 — 2.29 \cdot 10^8/m^2$) were noted in Bransfield Strait (Sts. 114 and 138) and the lowest ($0.62 — 1.08 \cdot 10^8/m^2$) in Drake Passage (Sts. 68 and 61).

Among the investigated stations the most remarkable and worthy of notice is St. 68, located about 10 km from the northern shores of King George I., where besides a rather small number of saprophytic bacteria the presence of fungi was also observed in the form of brown-coloured colonies growing on nutrient agar medium (Table I).

Total number of bacteria (TC) (Table II). The mean TC value was $2.14 \cdot 10^7$/l. The content of bacteria ranged from 0.16 up to $7.31 \cdot 10^7$/l, depending on the sampling spot. In general, higher bacterial concentrations were observed in the water layers from 0 to 50 m (average $2.6 \cdot 10^7$/l) than in the deeper water layers (avg. $1.3 \cdot 10^7$/l). The maximum TC values were recorded most often at the depth of 10 m (averege $2.95 \cdot 10^7$/l). The integrated TC values ranged from $1.74 \cdot 10^{12}$ m^2 (St. 138 on the Antarctic Peninsula shelf) to $5.76 \cdot 10^{12}/m^2$ (St. 151). The highest TC values were noted off the SE coast of King George I. (St. 151), off N coast of: Clarence I. (St. 53), Elephant I. (St. 181), King George I. (St. 68) and to the NW of Anvers I. (St. 94).

Dissolved organic carbon (Table III). DOC concentrations varied considerably

Table I.

Number of saprophytic bacteria in sea water samples on investigated stations

Depth (m)	colony forming units (CFU·10^3/l)									CFU·10^8/m^{-2}
	0	10	30	50	75	80	90	100	150	in water column from 0 to 150 m under 1 m^2
53	1.25	1.30	1.40	5.15	–	–	–	2.40	2.70	4.19
61	4.10	1.30	1.55	0.20	–	–	–	0.30	0.60	1.08
68*)	0.25	0.25	0.10	0.10	–	–	–	0.70	0.65	0.62
87	17.00	3.90	0.15	0.15	–	–	–	0.15	1.45	1.95
94	3.30	46.85	25.40	27.25	–	–	–	10.30	2.80	27.70
14	3.70	2.00	2.10	1.15	–	–	–	0.95	2.05	2.29
38	3.00	0.75	0.60	0.60	1.25	–	–	1.25	–	1.50
51	16.65	46.25	16.40	4.45	–	–	–	2.85	1.70	14.40
60	2.45	2.60	1.50	2.50	0.80	–	–	4.35	–	3.18
74	11.25	15.25	4.30	2.20	–	–	–	0.70	0.75	5.02
81	24.70	0.85	0.80	1.05	–	–	–	0.85	1.10	2.59
96	–	–	2.30	2.75	–	4.35	1.10	–	–	3.45

*) At the station 68 (depths 0, 10, 30 m) the abounding fungous growth was observed. CFU for fungi was 0.24, 0.56, 2.00·10^3/l, respectively.

Table II.

Total number of bacteria in sea water samples on investigated stations

Depth (m)	Bacterial number ($TC \cdot 10^7/l$)									$TC \cdot 10^{12}/m^2$
	0	10	30	50	75	80	90	100	150	in water column from 0 to 150 m under 1 m^2
53	1.60	2.85	1.76	2.24	–	–	–	2.20	1.83	3.20
61	3.59	4.29	3.30	0.83	–	–	–	0.48	0.26	2.08
68	2.60	5.06	2.88	4.68	–	–	–	1.38	0.42	3.70
87	1.28	2.92	3.40	2.05	–	–	–	1.06	0.16	2.46
94	0.80	0.99	0.67	5.74	–	–	–	1.09	0.32	2.92
14	2.34	2.72	2.69	0.38	–	–	–	1.31	0.67	2.02
38	1.79	1.79	1.38	1.67	0.42	–	–	0.38	–	1.74
51	6.31	4.49	7.31	2.56	–	–	–	3.30	2.79	5.67
60	0.93	1.67	1.63	1.03	1.31	–	–	1.25	–	2.01
74	2.56	1.76	2.24	1.63	–	–	–	1.15	1.54	2.37
81	4.52	3.68	3.49	2.85	2.02	–	–	2.72	2.27	4.19
96	–	3.14	1.76	0.96	–	0.80	1.41	0.82	–	1.87

Table III.

Organic carbon — dissolved (DOC) and particulate (POC) content in seawater samples in different stations

		mg/l									g m^2
	Depth (m)	0	10	30	50	75	80	90	100	150	in water column from 0 to 150 m under 1 m^2
53	DOC	0.37	0.24	0.51	0.85	–	–	–	2.25	1.50	195.4
	POC	0.11	0.10	0.11	0.09	–	–	–	0.06	0.07	12.1
61	DOC	0.82	1.36	1.02	0.48	–	–	–	0.54	0.89	110.9
	POC	0.05	0.05	0.06	0.04	–	–	–	0.05	0.03	6.8
94	DOC	0.95	0.75	0.48	0.48	–	–	–	0.48	0.48	78.4
	POC	0.23	0.25	0.24	0.23	–	–	–	0.03	0.03	20.0
114	DOC	3.02	0.43	0.57	0.29	–	–	–	0.77	1.66	123.1
	POC	0.09	0.11	0.03	0.06	–	–	–	0.02	0.02	6.3
138	DOC	0.27	0.07	0.27	0.75	0.34	–	–	0.20	–	53.5
	POC	0.08	0.09	0.04	0.03	0.02	–	–	0.02	–	5.9
160	DOC	0.30	0.00	0.85	0.17	1.40	–	–	0.71	–	99.3
	POC	–	0.06	0.07	0.10	0.09	–	–	0.08	–	12.4
196	DOC	–	0.89	1.77	1.50	–	1.43	0.89	1.09	–	207.9
	POC	–	0.03	0.03	0.02	–	0.02	0.02	0.02	–	3.5

Table IV.

Concentration of dissolved free aminoacids (DFAA) in seawater samples on investigated stations

Depth (m)	μmol/l									mmol/m²
	0	10	30		75	80	90	100	150	in water column from 0 to 150 m under 1 m²
53	0.1408	0.7324	0.5633	0.6761	–	–	–	0.8451	0.8451	109.9
61	0.1935	0.8000	0.3226	1.0323	–	–	–	0.4516	0.4516	89.4
68	0.0	0.0540	0.0	0.1081	–	–	–	0.2486	0.0540	18.3
87	0.0121	0.0303	0.0303	0.0242	–	–	–	0.0121	0.0061	2.7
94	0.1270	0.8889	0.5079	0.1905	–	–	–	0.0	0.0	30.7
14	0.0678	0.1357	0.4749	0.4749	–	–	–	0.2035	0.4749	51.0
38	0.7567	0.0	0.5946	0.1622	0.3243	–	–	0.0540	–	42.6
60	0.1379	0.1379	0.4138	0.0207	0.2759	–	–	0.2759	–	33.0
74	0.6207	0.4896	0.5172	1.8965	–	–	–	0.6207	1.3448	151.5
81	0.0690	0.2449	0.1379	0.2758	0.0690	–	–	0.2449	0.0690	25.6
96	–	0.2449	0.3592	0.2449	–	0.0	0.0	0.0	–	26.2

Table V.

Concentration of dissolved combined amino acids (DCAA) in seawater samples on investigated stations

Depth (m)	μmol/l									mmol/m²
	0	10	30	50	75	80	90	100	150	in water column from 0 to 150 m under 1 m²
53	1.6151	0.1476	0.6496	0.7404	–	–	–	0.7266	–	100.5
61	2.7335	1.4266	–	0.8515	–	–	–	0.6825	1.4067	156.0
94	0.2646	0.0	0.2856	0.3861	–	–	–	0.5993	0.5831	65.1
114	0.3598	1.1601	0.3830	0.8854	–	–	–	0.0	0.0	58.5
138	0.0	0.0	0.0	0.2137	0.9950	–	–	0.0	–	43.5
160	0.0	0.0	0.0	0.4896	0.0	–	–	0.0	–	16.5
196	–	0.2113	1.3886	0.2011		1.2082	2.9366	2.0113	–	163.5

Table VI.

Concentration of particulate combined amino acids (PCAA) in sea water samples on investigated stations

Depth (m)	μmol/l									mmol/m²
	0	10	30	50	75	80	90	100	150	in water column from 0 to 150 m under 1 m²
53	1.8347	1.3182	0.6130	1.8300	–	–	–	0.5906	–	180.0
61	–	0.0	–	0.0	–	–	–	0.0	0.7040	18.9
94	3.0215	1.8436	2.2214	1.2364	–	–	–	1.4065	–	249.0
114	1.2072	0.8396	1.3428	2.1956	–	–	–	0.6650	0.3768	165.0
138	0.0	0.1545	0.0	0.0	0.0	–	–	0.0074	–	3.7
160	0.1159	0.1642	0.0	0.4242	1.0406	–	–	1.0996	–	78.0
196	–	0.0	0.0	1.2607	–	0.2283	0.0	0.0	–	60.0

throughout the investigated area, ranging from 0.07 to 3.02 mg/l. No correlation with depth was observed, both, high and low values alike occurred at various depths of a given station. The integrated DOC values ranged from 53.5 g/m^2 at St. 138 (on the Antarctic Peninsula shelf) up to 195.4 and 207.9 g/m^2 at Sts. 53 and 196, respeeively (near Clarence I. and Elephant I.).

Particulate organic carbon (Table III). The POC content ranged from 0.02 to 0.25 mg/l. As regards its vertical distribution higher POC concentrations were observed mostly at 0 — 50 m depths. The integrated POC values ranged from 3.5 g/m^2 (St. 196) near Elephant I. up to 20.0 g/m^2 (St. 94) to the NW of Anvers I. The POC content made up, on an average, 8.5% of the total organic carbon content. Only at St. 94 the POC values was much higher and made up as much as 20.3% of the total carbon content.

Amino acids. The DFAA concentrations (Table IV) were in the range of 0 — 1.896 µmol/l, DCAA (Table V) 0 — 2.936 and PCAA (Table VI) 0 — 3021 µmol/l. The vertical gradients concentrations of the examined compounds were highly differentiated. The total content of the amino acids in the water column under 1 m^2 of the sea surface ranges for: DFAA from 2.7 (St. 87) to 151.5 mmol (St. 174), DCAA 16.5 (St. 160) to 163.5 mmol (St. 196) and PCAA 3.7 (St. 138) to 249.0 mmol (St. 94). The highest DFAA values averaging 117 mmol/m^2 were recorded at Sts. 61 and 174 localized in the open waters to the N and E of the South Shetlands and at St. 53 near Clarence I The lowest DFAA values

Table VII.

Organic carbon content (mg/m^3) in saprophytic (CFU) and total (TC) bacteria, in free (DFAA) and combined (DCAA) dissolved aminoacids and particulate combined aminoacids (PCAA), (calculated on the basis of integrated values).

No of station	CFU (x 10^{-5})	TC	DOC	POC	DFAA	DCAA	PCAA
53	8.23	0.63	1303.0	81.0	31.94	29.31	52.50
61	2.12	0.41	739.7	45.7	26.25	45.50	5.69
68	–	0.73	–	–	5.25	–	–
87	3.83	0.48	–	–	0.87	–	–
94	54.28	0.57	522.7	133.1	8.75	18.81	72.62
114	4.51	0.40	820.6	42.0	14.87	17.06	48.12
138	2.95	0.34	356.7	39.7	12.25	12.69	0.87
151	28.32	1.15	–	–	–	–	–
160	6.25	0.39	662.0	83.0	9.62	4.81	22.75
174	9.73	0.47	–	–	44.19	–	–
181	5.10	0.82	–	–	7.48	–	–
196	6.78	0.41	1386.1	23.3	7.66	47.69	17.50

were noted at St. 87 to the W of Smith I. At the remaining stations medium DFAA values of about 32 mmol/m^2 were observed.

The highest DCAA values averaging 140 mmol/m^2 occurred at Sts. 53, 61, 196 — near Elephant I. The lowest values were noted at St. 160 in the strait between the Antarctic Peninsula and Joinville I.

The highest PCAA values averaging 198 mmol m^2 were recorded at Sts. 94, 53 and 114 (near Anvers I., Clarence I., and Brabant I.) and the lowest values averaging 11.3 mmol m^2 at St. 61 (open waters of Drake Passage) and at St. 138 (on the Antarctic Peninsula shelf).

The organic carbon content in bacteria and amino acids are presented in Table VII for comparison with the total POC and DOC content in the investigated ecosystem. The organic carbon content in saprophytic bacteria averaged $1.9 \cdot 10^{-4}$ % of POC and total bacterial carbon made up 0.9% of POC. The carbon content in PCAA made up 49% of POC; in DFAA — 1.9% and in DCAA — 3% of DOC.

On the basis of the Sperman rank correlation analysis (Sachs 1974) the correlations of highest significance (at the level 0.01 and 0.025) were found between TC and PCAA, CFU and PCAA and less significant correlations at the level 0.050 between CFU and TC, TC and DCAA, DOC and DCAA, POC and PCAA, and at the level 0.1 between TC and DOC. In the arrangement of remaining data no-correlations were observed.

4. Discussion

Saprophytic bacteria, characterized on the whole by their ability to grow an agar nutrient, made up a very small (avg. 0.02%) fraction of the total number of bacteria. Most of these bacteria show characteristic features of psychrophilic bacteria, growing under culturing conditions at the temperature of 0—15°C. Equally small quantities of saprophytic bacteria, the range of 10^2 — 10^4, were observed earlier, in a close research area, during at the end of February and in the beginning of March, thus in a later part of the Antarctic summer (Zdanowski 1982), in the waters of Admiralty Bay during the Third (1979) and the Seventh (1983) Polish Antarctic Expedition to the Arctowski Station (Zdanowski unpubl.) and in other regions of the Antarctic Ocean (Wiebe and Handricks 1974).

During the present SIBEX programme, as regards the horizontal distribution of saprophytic bacteria the highst CFU values — just the same as during the FIBEX researches (Zdanowski 1982) — occurred to the NW of Anvers I. and at the — southern shore of King George I. and vertically — at a depth of 10—50, for the most part. Great differentiation was observed in the vertical distribution of sprophytic bacteria (CFU) despite the fact

that at most of the stations investigated during the present research (Sts. 53, 68, 114, 138, 151, 160, 181, 196) the waters under examination were rather strongly mixed (Grelowski and Tokarczyk 1985). Wide differentiation of the CFU vertical gradients was observed in both, the FIBEX and the present SIBEX experiments.

No bacteriostatic effects were observed in the areas with high phytoplankton concentrations. On the contrary, the highest phytoplankton and saprophytic bacteria concentrations were observed simultaneously, as well at present, as during the FIBEX investigations, e.g. to the NW of Anvers I. (Zdanowski 1982). During the present research the maximum POC and PCAA values were concurrent with maximum CFU counts. The PCAA values, which in this case may be regarded as an indicator of both phyto- and zooplankton biomass, were highly positively correlated (Table VIII) with the

Table VIII.

Spearman rank correlation matrix for relationships between saprophytic and total bacterial number and the following organic compounds: dissolved and particulate organic carbon (DOC, POC), dissolved free aminoacids (DFAA), dissolved combined aminoacids (DCAA) and particulate combined aminoacids (PCAA) (On the basis of integrated values).

	CFU	TC	POC	DOC	DFAA	DCAA	PCAA
CFU	1.00	0.71**)	0.46	0.21	−0.36	0.14	0.82***)
TC		1.00	0.32	0.54*)	0.11	0.68**)	0.86****)
POC			1.00	−0.36	0.11	−0.32	0.68**)
DOC				1.00	0.11	0.68**)	0.18
DFAA					1.00	0.00	0.00
DCAA						1.00	0.00
PCAA							1.00

*) **) ***) ****) significant at 0,10, 0.050, 0.025, 0.010 levels, respectively.

CFU values. Attempts were made, as during the FIBEX investigation, to examine the possible correlation between the occurrence of krill swarms and the abundance of saprophytic bacteria. By reason of an exceptionally low value of krill biomass throughout the season of the present investigations, the relevant determinations were carried out in one of the very few areas of the occurrence of a moderately dense krill swarm, at St. 196, near the shores of Elephant I. In the centre of that swarm the CFU values averaged $2.75 — 4.35 \cdot 10^3$/l (Table I), thus they did not differ from the average values observed over the whole research area.

Saprophytic bacteria play very important role in the natural environment. When particulate organic matter appears in the form of detritus, then saprophytic bacteria produce bacterial population dominant in number, colonizing remnants of dead organisms (Zdanowski 1981), or, as in the case of feaces, they penetrate from the animal intestines into the faeces

attacking their substance from the inside (Gowing and Silver 1983). Also, in the case of soluble matter, occurring in high overabundance under laboratory conditions as compared with natural concentrations, the predominance of saprophytic bacteria was observed — they made up as much as 90% of the total number of the recorded bacteria (Zdanowski — unpubl.).

Under natural conditions, after decomposition of the substratum, the saprophytic bacteria disperse throughtout the depths of the sea and they become again a low-numbered fraction of the total number of bacteria. It was demonstrated (Wiebe and Hendricks 1974) that the number of these bacteria in a valume of water is stabile in time and the measurements made on a given day are representative of a given site. These characteristic features of saprophytic bacteria may determine the role of bacteria as bioindicators of the oceanic water masses, as postulated much earlier by Kriss (1963).

The total number of bacteria determined during the present SIBEX investigations in early summer was at an exceptionally low level of TC values in the order of 10^7/l (Table I). In the average the TC values were five times lower than during analogical studies carried out in the same area between 15 February and 12 March 1981, within FIBEX programme (Zdanowski — unpubl). Earlier measurements of bacteria distribution carried out by Azam, Ammerman and Cooper (1981) in the Scotia Sea between Bransfield Strait and the South Orkney Islands in a still later part of the summer season (25 Feb. — 27 March 1981) show a more than ten times higher value of standing crop ($2.5 \cdot 10^8$/l) than the present result recorded during SIBEX. This indicates the occurrence of seasonal variability in the total number of bacteria. It was confirmed by the stationary one-year studies (Zdanowski — unpubl.) carried out at Admiralty Bay during the 7th Polish Antarctic Expedition to the Arctowski Station.

Between 9 April — 26 May, thus before the oncoming of winter, the total number of bacteria averaged $2.8 \cdot 10^8$/l at the water temperatures just above 0°C at the sea surface. Measurements made in mid-October, at the end of the Antarctic winter, at the surface water temperature −1.6°C, show a lower value (avg. $4.4 \cdot 10^7$/l) of the total number of bacteria. It seems that even relatively small (annual range 1—2°C) changes in temperature of the Antarctic waters have stronger effect upon the standing crop of bacteria than changes in the concentration of nutrients (Hanson and Pope 1981). Nutrient concentrations in the Antarctic waters are grossly excessive as compared with the lowest threshold level of of nutrients (about 1 nmol), that could limit the growth of bacteria (Hanson and Lowery 1983).

Thus, the temperature may be one of the factors in the Antarctic ecosystem controlling bacterioplankton life activity: proliferation and production (Hanson and Pope 1981), heterotrophic assimilation and DOM turnover (Hodson et al. 1981, Hanson and Lowery 1983) and capability of decomposition of perticulate organic matter, that results in the release of

great quantities of DOM (Jørgenson 1982, Rakusa-Suszczewski and Zdanowski 1980, Zdanowski 1981).

Bacterioplankton production seems to be rather an unimportant source of POM during present SIBEX expedition. The daily production of bacterioplankton, measured by Hanson and Lowery (1981), Hanson et al. (in prep.) (In: Hanson and Pope 1981), was less than 0.02 µg carbon per liter in January 1980, in Drake Passage, which makes on the average less than 4% of the total bacterial standing stock observed during the present SIBEX investigations (Zdanowski — unpubl.). This is a considerable value in relation to the bacterial standing stock but not much in relation to the total organic matter level. As results from Table VII, bacterial organic carbon averaged 0.9% of POC. The importance of bacterioplankton consists above all in the possibility of the uptake and mineralization of the dissolved compounds, even than when they occur in trace quantities (Poindexter 1981). One of the sources of a massive inflow of DOM into the oceans is phytoplankton, excreting metabolically cellular products into the environment (Lancelot 1979). Some authors are of opinion that about 50% of bacterial heterotrophic activities are connected with that fraction (Bell 1983). Bacteria are chief utiliters of DOM and they maintain it at stable level in the seawater.

On the basis of the studies carried out during the FIBEX and the present SIBEX programmes it is easy to notice that the areas with high and medium TC values coincide with areas of high phytoplankton concentrations in most cases, yet during the present SIBEX the maximum TC values observed in the areas of phytoplankton bloom were lower than those recorded in analogical areas during FIBEX investigations. On the other hand, no regular correlations between DOC and concentrations of phytoplankton and chlorophyll were observed during SIBEX (Kopczyńska and Ligowski 1985, Lipski 1985). In the area of the highest aboundance of phytoplankton bloom (St. 94) DOC concentrations were at a rather low level, whereas in another area (St. 53) fairly high concentrations of phytoplankton occurred simultaneously with large quantities of DOC (Table II). The question of the excretion of DOM by phytoplankton is not quite clear, yet. There are divergences of opinion (after Jørgensen 1982, after Griffiths, Caldwell and Morita 1982) as regards the stage of development of phytoplankton populations in which the release of DOM is the highest — whether it occurs in the course of bloom or in the next developmental phase. It is suggested that the excretion of DOM is the effect of various factors, among which the following are worth mentioning: age, physiological state and composition of phytoplankton populations (Bölter and Dawson 1982).

During the present SIBEX research, in general, lower DOC concentrations were recorded (Table III) than those given in the literature (after Pęcherzewski 1980). The maximum DOC values (1 - 3 mg/l), making up to 27% of the total DOC values, ranged at the level of the lowest values recorded

in 1980, at the beginning of the Antarctic summer season, by Bölter and Dawson (1982). The highest DOC concentration was observed (SIBEX) at the St. 196. near Elephant I, in water samples collected in the middle of a krill swarm (Table III).

As regards POC, the highest values were noted in the areas great abundance of phytoplankton and chlorophyll a (Sts. 53, 94, 160) at 0—50 m depths. The POC concentrations during the present SIBEX investigations were however much lower than those cited by Pęcherzewski (1980), Most of the stations of the present measurements were localized in the regions poor in phytoplankton, therefore the mean POC value is very low (0.064 mg/l).

The DFAA and DCAA contents, during the present investigations, averaged 350 and 570 nmol, respectively, i.e. they did not diverge from the mean values recorded in other regions (Jørgenson 1982). A comparison with the data obtained earlier by Mężykowski (1982) and Bölter and Dawson (1982) in the Antarctic regions, covered by both the FIBEX and SIBEX programmes, shows similarities in DFAA concentrations and wide differences in DCAA concentrations, which were generally much lower during SIBEX investigations. The maximum DCAA values during SIBEX were five times lower than the maximum values obtained during FIBEX measurements. Another difference worth mentioning: more regular (than during SIBEX) distribution of DFAA throughout the area investigated during FIBEX. Moreover, during present SIBEX research, the complete absence of DFAA and DCAA was observed in various sites, whereas during FIBEX it was not the case (Tables IV and V).

No correlation was observed between the occurrence of DCAA and DFAA and that of phytoplankton. On the other hand in the area of the occurrence of krill swarms (St. 196) near Elephant I. the highest during SIBEX DCAA value and a very low DFAA content were recorded. In a laboratory experiment, carried out on board of the vessel and involving the measurements of the DFAA content in the sea water used in krill cultures, no traces of the DFAA excretion were found. Injuries, symptoms of the worsening of the general condition and death of krill caused an immediate increase of DFAA in water containing krill (Zdanowski — unpubl.).

High PCAA values were associated with the aboundance of phytoplankton. The greatest quantities of phytoplankton and of PCAA were observed at St. 94 localized to the NW of Anvers I. High PCAA values were associated with high POC values. Yet, in the whole area of the investigations, these two parameters did not occur proportionally to each other, that is evidenced by variable percentage of amino aicd carbon in POC, ranging from 2.2 to 75.1% (Zdanowski — unpubl.).

In conclusion: The total number of bacteria and concentrations of POC, DOC, and DCAA in the regions of the present SIBEX investigations

during the early part of the 1983—1984 summer season were in general much lower than the results obtained in provious years, mostly in the later part of the Antarctic summer. The number of saprophytic bacteria and the concentrations of DFAA and PCAA were at about the same level as in the precedent years. As regard the vertical distribution, the highest TC, CFU, POC and PCAA concentrations were recorded in the 0—50 m water-layers. A higher number of bacteria was noted in the areas with greater abundance of phytoplankton.

5. Резюме

Пространственное распределение свободно обитающих бактерий и органических компонентов среды исследовалось в период с декабря 1983 до января 1984 года в южной части пролива Дрейка и в проливе Брансфилда, т.е. в районе экологических исследований программы БИОМАСС-СИБЭКС (рис. 1). Пробы воды отбирались на 12 океанографических станциях с шести стандартных горизонтов от 0 до 150 м. Бактерии определяли методом эпифлуоресцентной микроскопии, а также методами пластинчатым и мембранных фильтров, органический углерод методом Menzel и Vaccaro (1964), аминокислоты флуорометрическим методом с офтальдегидом. Результаты представлялись в соответствующих единицах на 1 литр морской воды, а также как интегрированные величины для столба воды 0—150 м под 1 м^2.

Общее количество бактерий (TC) колебалось от 0,16 до $7{,}31 \times 10^7$/л, и 1,74—$5{,}67 \times 10^{12}$/м^2 (таблица II), количество сапрофитических бактерий (CFU) 0,10—$46{,}85 \times 10^3$/л и 0,62—$27{,}7 \times 10^8$/м^2 (таблица I), содержание взвешенного органического углерода (POC) (таблица III) 0,02—0,25 мг/л и 3,5—20,0 г/м^2, содержание растворенного органического углерода (DOC) 0,07—3,02 мг/л и 53,5—207,9 г/м^2 (таблица III), растворенные свободные аминокислоты (DFAA) (таблица IV) 0—1,8965 мкмоль/л и 2,7—151,5 ммоль/м^2, растворенные связанные аминокислоты (DCAA) 0—2,9366 мкмоль/л и 16,5—163,5 ммоль/м^2 (Таблица V), взвешенные связанные аминокислоты (PCAA) (таблица VI) 0—3,015 мкмоль/л и 3,7—249,0 ммоль/м^2.

Была установлена значительная дифференциация численности бактерий и содержания органического углерода на исследуемой территории. Высокие и низкие значения отдельных параметров были мозаично перемешаны. Вертикальные градиенты контицентрации бактерий и изучаемых соединений были дифференцированы. Установленные закономерности это более частое присутствие высших значений TC, CFU и POC на глубине 0—50 м, чем в низших слоях, а также (как и во время ФИБЕКС) присутствие найвысших значений TC и CFU вблизи скоплений фитопланктона.

Получение значения в принципе сравнимы со значениями, установленными в других географических районах Мирового океана. Содержание органического вещества достигает довольно высокого уровня в пределах, установленных в Мировом океане. В сравнении с предыдущими исследованиями, проведенными в том же районе антарктивеских вод, нынешние исследования покзали снижение общего количества бактерий и содержания органических соединений в воде, что может быть, связано с ранным периодом антарктического лета. Численность сапрофитических бактерий наблюдалась на типичном для антарктических вод уровне 10^2—10^4 CFU/л, что свидетельствует о большой стабильности численности этой группы бактерий.

Анализ корреляции между TC, CFU и PCAA, а также между TC, DOC, DCAA и PCAA обнаружил присутствие существенных положительных корреляций.

6. Streszczenie

Przestrzenne rozmieszczenie wolno żyjących bakterii i organicznych komponentów środowiska było badane na przełomie grudnia i stycznia 1983/84 w rejonie Cieśniny Drake'a i Cieśniny Bransfielda, objętym kompleksowymi badaniami ekologicznymi podczas BIOMASS-SIBEX (rys. 1).

Próbki wody pobrano z 12 stacji oceanograficznych z sześciu standardowych poziomów od 0 do 150 m. Bakterie oznaczano metodą mikroskopii epifluorescencyjnej oraz metodą płytkową i filtrów membranowych, węgiel organiczny metodą Menzel i Vaccaro (1964), aminokwasy metodą fluorometryczną z o-phthalaldehydem. Wyniki wyrażano w odpowiednich jednostkach na 1 l wody morskiej, oraz jako wartości zintegrowane dla słupa wody 0—150 m pod 1 m^2.

Ogólna liczba bakterii (TC) wahała się od 0.16 do $7.31 \cdot 10^7$/l i $1.74 - 5.67 \cdot 10^{12}/m^2$ (tabela II), liczba bakterii saprofitycznych (CFU) $0.10 - 46.85 \cdot 10^3$/l i $0.62 - 27.7 \cdot 10^8/m^2$ (tabela I), zawartość całkowitego węgla organicznego (POC) 0.02 — 0.25 mg/l i 3.5 — 20.0 g/m^2, rozpuszczalnego węgla organicznego (DOC) 0.07 — 3.02 mg/l i 53.5 — 207.9 g/m^2 (tabela III), rozpuszczalnych, wolnych aminokwasów (DFAA) 0 — 1.8965 µmol/l i 2.7 — 151.5 mmol/m^2 (tabela IV), rozpuszczonych, związanych aminokwasów (DCAA) 0 — 2.9366 µmol/l i 16.5 — 163.5 mmol/m^2 (tabela V), partykularnych związanych aminokwasów (PCAA) 0 — 3.015 µmol/l i 3.7 — 249.0 mmol/m^2 (tabela VI).

Stwierdzono znaczne zróżnicowanie liczebności bakterii i zawartości organicznej materii na badanym obszarze. Przeważnie wysokie i niskie wartości poszczególnych parametrów były mozaikowo wymieszane, gradienty pionowe stężeń bakterii i badanych związków były bardzo zróżnicowane. Stwierdzone prawidłowości to częstsze występowania wyższych wartości TC, CFU i POC na głębokości 0—50 m niż w warstwach głębszych oraz (podobnie jak podczas FIBEX) występowanie najwyższych wartośc TC i CFU w miejscu występowania skupień fitoplanktonu.

Otrzymane wartości są generalnie porównywalne do wartości otrzymywanych w innych rejonach geograficznych wszechoceanu. Zawartość materii organicznej występuje na dość wysokim poziomie w zakresie spotykanym we wszechoceanie. W porównaniu z poprzednimi badaniami prowadzonymi w tym samym rejonie wód antarktycznych, niniejsze badanie wykazały obniżenie ogólnej zawartości bakterii i zawartości związków organicznych w wodzie, co może być związane z wczesną porą lata antarktycznego. Standing stock bakterii saprofitycznych występował na typowym dla wód antarktycznych poziomie $10^2 - 10^4$ CFU/l, co świadczy o dużej stabilności liczebności tej frakcji bakterii.

Analiza korelacji szeregów Spermana (Sperman rank correlation), wykazała występowanie istotnych dodatnich korelacji pomiędzy TC, CFU i PCAA oraz korelacji pomiędzy TC, DOC, DCAA i PCAA.

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