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Variations of physical conditions, nutrients and chlorophyll *a* contents in Admiralty Bay (Kind George Island, South Shetland Islands, 1979)

ABSTRACT: In 1979 54 water samples were collected at two oceanographic stations located in Admiralty Bay. Ranges of seasonal changes were found for the values of ten parameters: water temperature, salinity, dissolved O, pH, the contents of PO_4, Si, NO_2, NO_3, chlorophyll *a* and plant carotenoids at six depths between surface and 400 m. Data for temperature and salinity showed the absence of distinct thermoclines or haloclines which reflects the very low stability of waters in the Bay. The concentrations of nutrients were high during the entire year and they were not limiting for phytoplankton growth. Only nitrates decreased distinctly during algal blooms. The high dynamics of waters in the Bay causes a lowering in the chlorophyll *a* content to a maximum of about 2 mg/m^3. Oceanographic, hydrochemical and hydrological conditions in Admiralty Bay are typical for the Antarctic shelf waters in this geographical region.

Key words: Antarctica, Admiralty Bay, hydrology.

1. Introduction

Marine ecosystem plays a key role in the Antarctic (Hedgpeth 1977). The area of near shore waters is a particularly important part of this ecosystem, and is often decisive about its functioning (Rakusa-Suszczewski 1980). Because of the variety of factors acting there, and the difference from the open ocean zone (Lafond and Lafond 1971), the coastal waters are especially interesting for studies in hydrochemistry and hydrobiology. In the past, several studies were done in these areas which concentrated on the seasonal changes of various physical and chemical parameters of sea water. Bunt (1960) reported investigations conducted near Mawson station in June 1956 — February 1957. Tressler and Ommundsen (1962) initiated more than 20 months lasting studies in the McMurdo Strait which were continued by Littlepage (1965) in January — December 1961. Čikovskij (1969), besides data on hydrological parameters, presented seasonal variations of temperature and salinity observed during the 10th Antarctic Expedition in the area close to Mirnyj Station at Davies Sea during the entire year of 1965 and in January 1966. Argentinian scientists, Bienati and Comes presented (1970) the results of research projects conducted in the years 1965, 1967 (surface data) and in 1968 (samples taken down to 90 m) in the Paradise Harbour in the vicinity of Almirante Brown Station. They measured water temperature, salinity, water transparency, pH, oxygen content, phosphates, nitrites and alkalinity. In the period March 1967 — January 1968 near Syowa Station under ice cover down to 90 m depth Hoshiai (1969) measured the changes in salinity, dissolved oxygen, pH and chlorophyll *a*. In the period from June to October 1969 Rakusa-Suszczewski (1972) measured temperature, oxygen and silicates (to the depth of 137 m) in Alašev Bight close to Soviet Station Molodežnaja. The results of more than two-years lasting studies (December 1971 to January 1974) in Arthur Harbour near Palmer Station are shown by Krebs (1974, 1983). Tanner and Herbert (1981) describe the changes in the contents of chlorophyll *a*, nitrates, ammonia and phosphates near Borge Bay (Signy Island) from the middle of 1976 to the middle of 1977. Changes in the chlorophyll *a* content are also shown by Bienati, Comes and Spiedo (1971) from Paradise Harbour and by Whitaker (1982) from Borge Bay.

None of the works cited before shows simultaneously a complete annual cycle of all the macronutrients (nitrogen, phosphporus, silicon), the physical parameters of sea water such as temperature and salinity, and of chlorophyll *a*. The investigations conducted in 1979 in Admiralty Bay fill in this gap.

Research area

Admiralty Bay (Fig. 1) is a large water body which widely opens towards the Bransfield Strait. It has a surface area of 119 km and a water volume of ca 21 km^3 (Fedak and Marsz, in press). Depths in the central area of the bay reach 400—500 m, with a maximum of 530 m. Depths in the main inlets of the bay — the Ezcurra, Mackellar and Martel are much shallower and rarely exceed 100 m. Cross sections of the central area in the bay have the shape of the letter U, thus are typical for fiords. Bottom in the main part of Admiralty Bay is smooth without underwater terracess or shallows. Bottom configurations in the inlets are

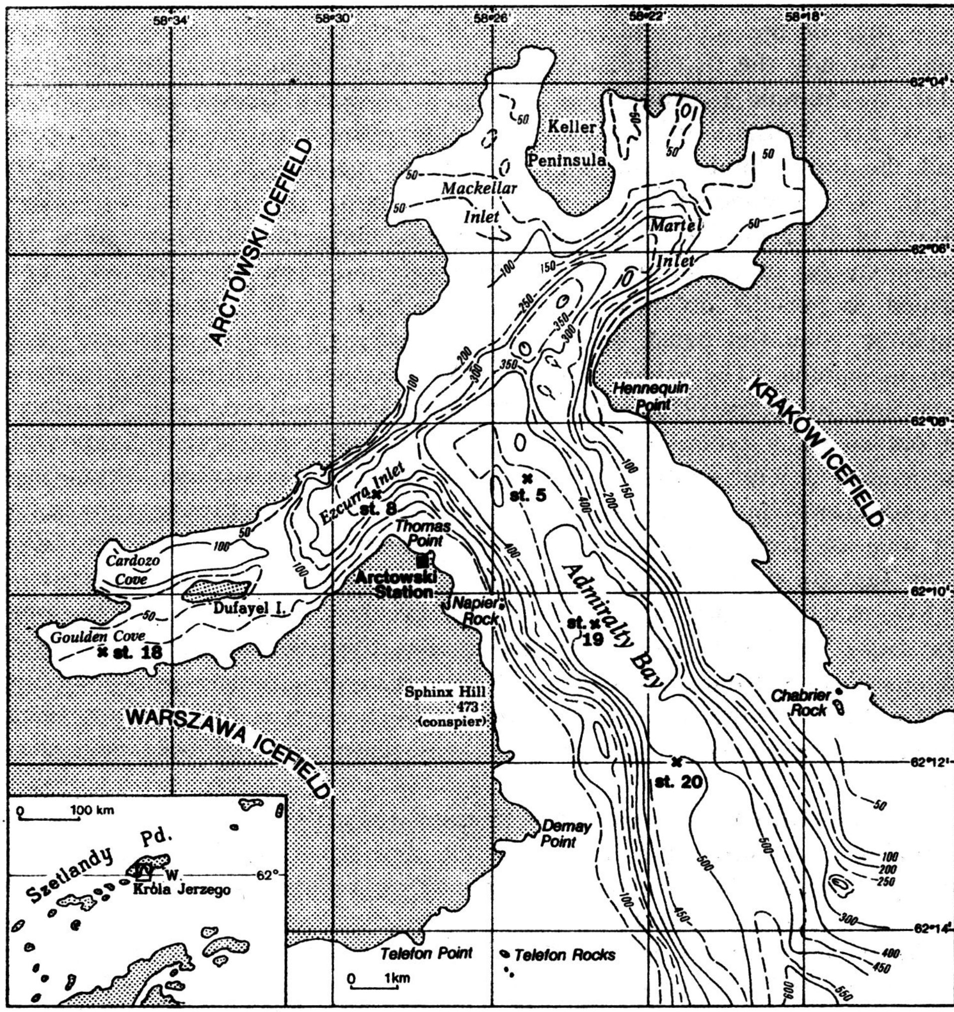

Fig. 1. Position of the oceanographic stations in the Admiralty Bay. The map is redrawn after Admiralty Chart No. 1774, bathymetry after chart of K. Furmańczyk and A. Marsz 1980 — Admiralty Bay

more varied, for example the underwater terrace in Ezcurra Inlet, or the extensive shallow areas in Mackellar Inlet.

About 46% of the shore line is taken up by glacier fronts or ice falls. Many surface and under ice streams that are bringing melted waters into the bay contain large amounts of suspended mineral matter (Pęcherzewski 1980) and cause a decrease in salinity in the surface stratum of the bay. The inflow of melt waters continues even when the mean daily air temperature falls below — 10°C.

The quantities of suspended mineral matter alter the hydrooptical properties of the waters in the bay and affect the depth of the euphotic zone. Already the first investigations in 1975/76 done during the I Polish Marine Antarctic Expedition in the region of King George Island (Wensierski and Woźniak 1978) showed that the waters are not very transparent and the lower limit of the euphotic zone sometimes lies at about 20 m depth. Works conducted in Ezcurra Inlet during the II Antarctic Expedition of PAS in 1977/78 (Woźniak, Hapter and Maj 1983) and also the measurements taken during FIBEX (Stramski and Montwiłł 1982) had confirmed the results obtained during the I Expedition. The depth of the euphotic zone fluctuated between 15 and 42 m with the mean of 23 m for the summer. The values of the spectral coefficients of light attenuation, according to Jerlov 1976), qualifies the waters of the Bay to the III group of optical water types, that is to near shore waters with large amounts of suspended mineral matter. All these results pertain to summer conditions.

Admiralty Bay is located in the zone of Antarctic marine climate in an area of deep atmospheric lows (Moczydłowski 1978, Marsz and Rakusa-Suszczewski in press). This results in two prevailing wind directions: WSW exactly along the long axis of Ezcurra Inlet and NWN along the axis of the main basin of Admiralty Bay towards the Bransfield Strait. Winds blowing from these two directions affect the hydrological conditions in the bay. On the average the period of ice coverage lasts about three months, there are years however, like 1979, when ice cover does not occur at all.

At the latitude of Arctowski Station (62° 10'S) the following sun altitudes are noted: minimum 4°36′ at day length of 5 hours 6 min., and maximum 51°18′ at day length of 19 hours 51 min. (Marsz and Rakusa-Suszczewski 1986).

Tides and currents in Admiralty Bay have not been well investigated as yet. Preliminary works (Catewicz 1983, Catewicz and Kowalik 1983) showed that tides are of the mixed type, irregular semidiurnal. In addition there is a significant influence of the syzygial and quadratural tides. The average height of the semidiurnal tide is 158 cm. Investigations of currents (Pruszak 1980) showed that surface currents are generated by local wind fields. Only at wind speed below 3 m/sec. the influence of tidal phenomena on currents becomes essential. Surface currents generated by wind reach down only to less than 20 meters. Deep currents are caused by tidal phenomena: water flows into Admiralty Bay near bottom and outflows in the surface stratum.

Materials and methods

The works were conducted in the period between 29 December 1978 and 4 December 1979. Water samples were collected three times a month at two main oceanographic stations No 5 and 8. In addition, surface water was collected at stations 18, 19 and 20. Numbers of oceanographic stations were kept the same for all teams working on the sea in the season 1978/79 (Samp 1980, Pęcherzewski 1980, Szafrański and Lipski 1982) and thus they are also used for convenience in the present paper (Fig. 1).

Altogether 26 water samples were collected at station 5; 28 at station 8, and 6 surface samples from each of the stations 5, 8, 18, 19 and 20. According to the results of t-student test, the differences between annual averages for

Table 1

Geographical coordinates and depths of oceanographic stations in Admiralty Bay

Station No	Latitude S	Longitude W	Depth [m]
5	62°08.7′	58°25,1′	410
8	62°08.8′	58°28,9′	240
18	62°10,7′	58°35,8′	70
19	62°10,4′	58°23,4′	480
20	62°12,0′	58°21,3′	500

stations 5 and 8 are not significant, therefore only data of station 5 are presented here to illustrate the seasonal changes of measured parameters. Water samples were collected from board of a fishing motor boat „Dziunia" especially adapted for purposes of hydrological works. Because of technical limitations, samples at two main stations were taken only from 0, 25, 50, 100, 200 m and about 10 m above the bottom. In the case of station 8, 200 m level was excluded because of a small difference from the above-bottom-level of 230 m. Water samples were taken with a reversable bathometer of the BM-48 type having reversable thermometers and also with a Van Dorn type 6-lit plastic bathometer (Kahlsico, USA). Measurements of nutrients, pH, chlorophyll and plant carotenoids were carried out accordingly to the methods described in the handbooks — Strickland and Parsons (1968) and FAO Fisheries Technical Paper (1975). The following methods and instruments were used:

For water temperature the mean from readings of two reversable thermometers was considered;

Salinity was found using the Plessey Model 6230 N laboratory salinometer;

Dissolved oxygen was determined by the Winkler method, and percent of oxygen saturation was calculated numerically according to equation given in International Oceanographic Tables Vol. 2 (1973);

pH: unfiltered samples were kept at 20°C and measured with a Mera-Elwro N-5122 pH-meter; results were corrected to values in situ according to equation given in FAO Fisheries Technical Paper No. 137. Prior to each series of measurements the pH-meter was standardized against two certified pH standards;

Nutrients and plant pigments were measured with a Spekol apparatus spectrophotometer (Carl Zeiss Jena, GDR);

Phosphates (dissolved inorganic phosphorus) were determined with the method of Murphy and Riley (1962) using ascorbic acid as reductor;

Silicates (reactive silicates) were determined with the "blue" method of Grasshoff (1964); ascorbic acid was used as a reductor;

Nitrites were measured according to a modified method of Bendschneider and Robinson (1952);

Nitrates were found with the Bendschneider and Robinsons' method (1952). Columns with metalic cadmium were activated according to Grasshoff (1976).

Determinations of plant pigments were based on methods given by Strickland and Parsons (1968), Tolstoy (1977) and recommendations of the Baltic Marine Biologists (Publ. No 5) edited by Edler (1979).

Because of a disturbing effect of fucoxanthine (Riemann 1978) which occurs in diatoms in significant quantities, the spectrophotometric procedure of Lorenzen (1967) could not be used for seperate determinations of chlorophyll *a* and of pheopigments.

The results of measurements obtained during each sampling were worked out by a computer. Calculations were made of: Sigma T values, percent of oxygen saturation, weighted means, coefficients of variation for vertical changes for a given parameter and also integrated values in the water column by means of trapezoidal method. Full set of this data, in form of a computer printout, is enclosed in M. Lipski Ph. D. Thesis.

Results

1. Water temperature

Seasonal change in water temperature is contained within narrow limits between the temperature of freezing (−1.8°C) and about +1.8°C (Fig. 2). At the depth of 400 m this range is even more narrow i.e. less than 1.5°C (Table 2). There is a lack of a distinct thermocline during the entire year. Changes in temperature are gradual, the values of gradients are small and less than 0.01°C/m. Any greater temperature changes, noted down to more than 10 meters, as was ascertained by bathythermographic measurements of Szafrański and Lipski (1982), were associated with diurnal changes. From the typical for the summer gradual lowering in temperature with increasing depth, the water becomes almost entirely izothermic from surface to bottom in April and May until the onset of a reversed winter temperature configuration.

Table 2.

Annual means (x̄), minimal and maximal values, standard deviations (S) and coefficients of variations (W%) of parameters measured at Station 5 during 1979 (Extremal Values in all sampling depths are underlined)

Depth m		T °C	S ‰	Sigma T	O_2 cm^3/dm^3	O_2 satur. %	pH	PO_4 μgat/dm³	Si μgat/dm³	NO_2 μgat/dm³	NO_3 μgat/dm³	chlor.a mg/m³	plant. karot. mg/m³
	min.	**−1.77**	**33.41**	**26.74**	7.11	87.9	8.12	1.26	74.8	0.015	11.3	0.07	**0.00**
	max.	**1.76**	34.16	27.51	**8.32**	**102.3**	8.27	**2.40**	90.0	0.370	33.2	**1.97**	1.14
0	x̄	−0.4035	33.9704	27.31	7.6712	93.6	8.1946	1.8377	84.2423	0.1919	26.5654	0.3615	0.1423
	S	1.1663	0.2110	0.2180	0.3158	3.6061	0.0393	0.3072	3.7467	0.0966	6.6919	0.4336	0.2272
	W	300.64	0.65	0.80	4.28	3.85	0.50	17.39	4.63	52.33	26.20	124.74	166.00
	min.	−1.76	33.59	26.94	6.89	86.6	8.12	1.09	**73.1**	0.035	8.2	0.04	**0.00**
	max.	1.67	34.16	27.52	8.20	100.2	8.26	2.28	90.0	0.374	33.8	1.82	**1.15**
25	x̄	−0.4415	34.0488	27.38	7.5950	92.6	8.1927	1.6996	84.4115	0.1823	26.7000	0.4015	0.1400
	S	1.1397	0.1246	0.1437	0.3472	3.5418	0.0384	0.3559	3.9812	0.0944	7.2455	0.4050	0.2304
	W	268.46	0.38	0.52	4.75	3.82	0.49	21.78	4.91	53.86	28.23	104.90	171.13
	min.	−1.73	33.99	27.24	6.40	80.9	8.11	0.99	76.6	0.046	**6.3**	0.10	**0.00**
	max.	1.25	34.20	27.55	8.22	100.5	8.26	2.28	91.0	0.363	33.8	1.29	0.78
	x̄	−0.4450	34.1119	27.43	7.5027	91.5	8.1892	1.7127	85.1923	0.1869	26.5500	0.3181	0.1169
50	S	1.0756	0.0611	0.0888	0.4248	4.1410	0.0374	0.3236	3.6805	0.1025	7.1515	0.2727	0.1611
	W	251.37	0.19	0.32	5.40	4.52	0.48	19.65	4.49	57.11	28.02	89.16	143.31
	min.	−1.70	34.04	27.30	6.38	80.6	8.08	1.20	76.0	0.015	10.9	0.07	**0.00**
	max.	−1.70	34.04	27.30	6.38	**80.6**	8.08	2.14	92.7	0.358	33.9	0.54	0.30
	max.	0.97	34.26	27.59	8.04	97.6	**8.30**	1.7754	86.3000	0.1777	28.6961	0.2181	0.0550
100	x̄	−0.4719	34.1769	27.48	7.2496	88.4	8.1885	0.2672	3.4300	0.1001	5.6143	0.1224	0.0649
	S	0.9406	0.0482	0.0619	0.4540	4.0480	0.0459	15.65	4.13	58.60	20.34	58.38	122.68
	W	207.28	0.15	0.23	6.51	4.58	0.58	1.31	76.1	0.015	16.9	0.05	**0.00**
	min.	−1.53	34.20	27.47	5.86	73.8	8.06	2.12	94.5	**0.532**	33.4	0.27	0.14
	max.	0.61	34.56	27.77	7.56	90.8	8.24	1.7631	89.7885	0.1796	29.2346	0.1365	0.0300
	x̄	−0.4619	34.3162	27.58	6.7800	83.1	8.1685	0.2711	3.6248	0.1196	4.9811	0.0591	0.0348
200	S	0.7100	0.0730	0.0592	0.4680	4.7239	0.0459	16.00	4.20	69.22	17.72	45.03	120.50
	W	159.86	0.22	0.21	7.18	5.71	0.58	**0.68**	87.0	**0.010**	21.2	**0.00**	**0.00**
	min.	−1.15	34.40	27.54	**5.10**	**63.4**	**8.03**	2.30	**102.0**	0.472	**34.4**	0.24	0.04
	max.	0.28	34.62	**27.85**	7.29	89.0	8.24	1.7473	94.2923	0.1350	31.2731	0.0792	0.0085
	x̄	−0.4612	34.4915	27.73	6.1731	75.5	8.1519	0.3751	3.9868	0.1048	3.0382	0.0508	0.0141
400	S	0.4403	0.0579	0.0574	0.5149	5.7623	0.0502	22.33	4.40	80.71	10.11	66.61	172.72

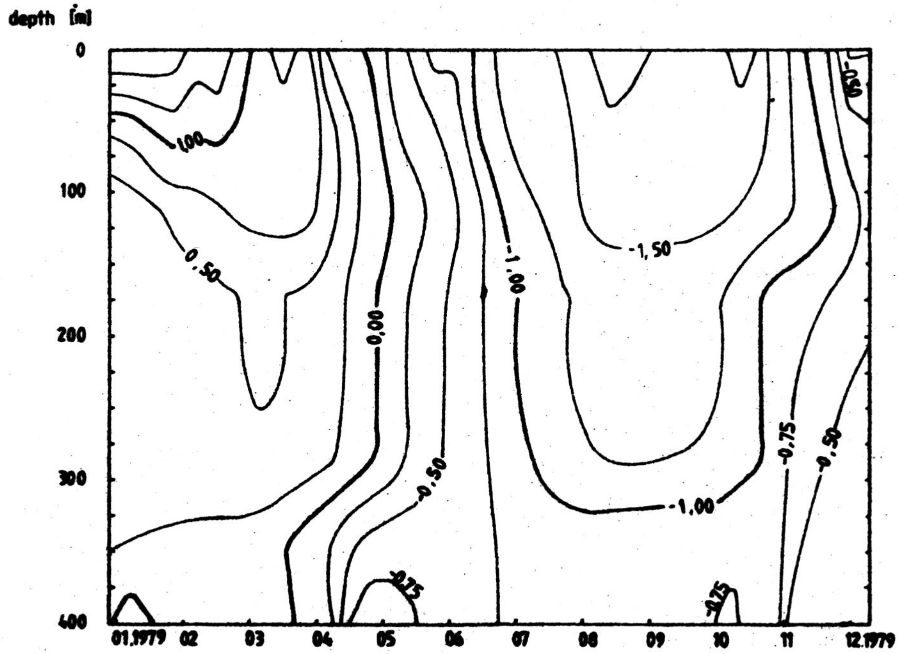

Fig. 2. Annual variation of sea water temperature in the Admiralty Bay at Station No. 5

The difference between surface temperature and at 400 m is no more than 2°C in summer, and it is 1°C in winter. At the begining of winter, temperature maxima occur at 50—100 m, while at the beginning of summer the same depths have the lowest temperatures. Occasionaly, at the depth of 400 m water temperature did not correspond to the temperatures of the overlaying water. Analysis of other parameters of this water led to the conclusion that these were sporadic inflows of water of different origin which take place in the near bottom stratum of the main basin of Admiralty Bay. It turned out, that mean annual values of temperature are very similar at all depths (Table 2). They are between −0.40°C and −0.47°C at station No 5, and between −0.30°C and −0.42°C at station No 8. At both stations, the highest temperature means were noted for the surface measurements. The absence of a distinct thermal stratification of water and very similar results obtained from stations Nos. 5 and 8 points out the high dynamics of waters in Admiralty Bay.

2. Salinity

The most characteristic feature of seasonal variations in salinity is the occurrence in summer, from surface to 50 or 75 m, of a water layer with a distinctly lowered salinity (Fig. 3). The lowest recorded surface value was 33.41°/₀₀ compared to the annual mean of 34.00°/₀₀. At the end of summer, surface salinities gradually increase to reach finally the typical winter values of 34.05—34.15°/₀₀. The highest salinity values were noted at the surface from July to September. In the water layer below 100 m seasonal

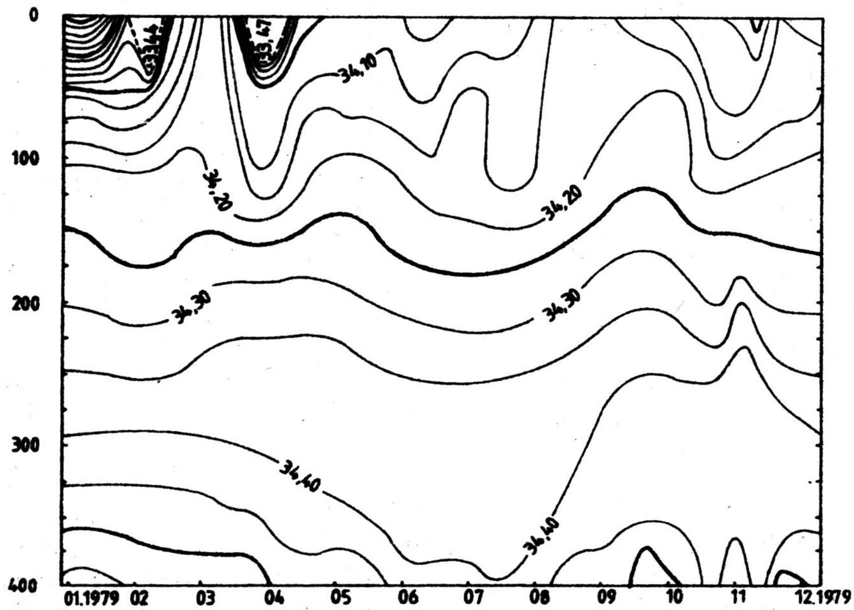

Fig. 3. Annual variation of salinity in the Admiralty Bay at Station No. 5

changes are very small and any fluctuations at values which do occur are caused mainly by the dynamics of water exchange in the Bay, or by vertical water movements, not by the summer salinity decrease. At the near bottom layer, salinity fluctuations are small, below 0.2°/₀₀ during the year, and the seasonal mean is 34.49°/₀₀. Especially interesting is the comparison of fluctuations of salinity from surface to 50 m for stations 5 and 8. Lower salinity values, including individual measurements and annual means for station No 5, located in deeper water, further from shores and inflows of fresh water, suggest that in the vicinity of station No 8 local near-shore upwelling occurs. It is also clear, that a local inflow of fresh water had a small effect on the salinity of the whole water volume of the Bay. Low salinity water (values less than 20°/₀₀) was found in summer very close to the fresh water inflows (Szafranski and Lipski 1982). This phenomenon was of microscale range (thickness of low salinity layer not exceeded 1 m).

3. Relative density SIGMA-T

Relative density values, and especially the picnoclines have a significant effect on the development of phytoplankton and microzooplankton which inhabit a given water mass. The calculated values of relative density range from 26.74 in warm surface waters of substantially lowered salinity, to 27.85 in near bottom waters during winter. Similarly as for temperature and salinity there were no sharp changes in density. In all cases, density gradually increased with depth; in summer the difference between surface and 400 m depth reaches 1.06 units, while in winter it is much less with 0.2—0.4. It is interesting, that as for salinity, the lowest values of relative density occurred at station No 5, and the seasonal means for depths between 0 and 100 m are just slightly greater for station No 8. With the lack of picnoclines and with small vertical variations in density, the waters of Admiralty Bay have very poor stability.

4. Water transparency

Water transparency as measured by the Secchi disc gives a general information about light in water available for the processes of photosynthesis. The major factor which lowers transparency of water in the bay is the inflow of fresh waters bringing large quantities of suspended mineral matter. In summer Secchi disc disappeared at the depth of 3 or 4 meters. In stations located at the end of secondary bays — inlets Secchi disc was not visible below 2 m. With lowering of air temperature and gradual freezing of soil, the inflow of melt waters stops, while sea water becomes more and more transparent and Secchi disc visibility increased to 32 meters. It happens at the end of August and the begining of September. During summer, a typical content 10 to 13 mg/dm^3 of suspended particular matter lowers the Secchi disc visibility to 3—3.5 m. In winter, visibility of 30 m corresponds to content of 2.5 mg/dm^3.

5. Dissolved oxygen

Dissolved oxygen content in Admiralty Bay was high over the entire year and revealed very characteristic seasonal variations (Fig. 4). Rather high oxygen content observed at the end of December and the begining of January gradually decreases to the minimum of surface values (6.7 ÷ 7.1 cm^3/dm^3) in the second half of March and in the begining of April. Following this period there was an increase of oxygen values to a winter maximum of 8.1 cm³/dm³ which occurs at the turn of July and August. In September and at the begining of October oxygen content decreased again especially noticeably in the water layer down to 100 m. From the middle of October, the oxygen content rose suddenly, mainly in the euphotic zone, what was undoubtedly caused by a rich development of phytoplankton. During this period, maximum values of oxygen were found sometimes at 25—50 m.

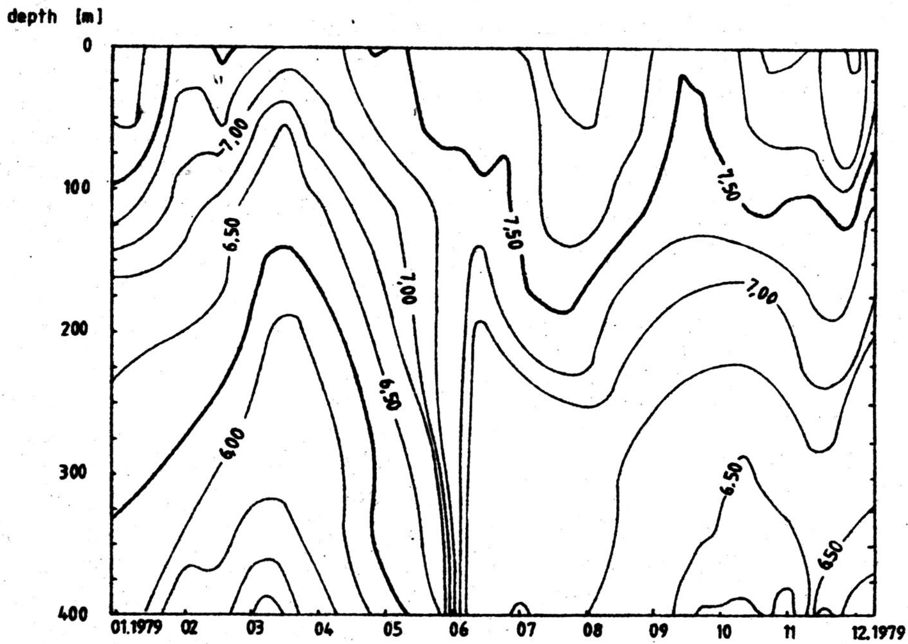

Fig. 4. Annual variation of oxygen content in the Admiralty Bay at Station No. 5

A comparison of oxygen and salinity data shows, that oxygen minimum which occurred from the begining of March till the first days of April corresponded to a large scale exchange of water in the bay. Similar situation ocurred in September and at the begining of October. The picture of oxygen content in the bay as shown in figures of percent saturation is very interesting. It turned out, that in spite of high absolute oxygen values, the waters in the bay very rarely reach 100% of oxygen saturation. The annual mean for surface water was 93.5%. Oxygen oversaturation was noted only twice: in January with the values about 100.5% at surface and 50 m depth, while in November during first phytoplankton bloom oxygen oversaturation (max. to 102.3%) occurred down to 100 m depth. Compared to other oceanic regions the oxygen oversaturation values encountered in Admiralty Bay are small.

6. pH (in situ)

During the period of measurements pH values changed only within a narrow range from 8.1 to 8.2 (Fig. 5). Only at the end of November, at 100 m depth there was a distinct increase to pH 8.3 at station No 5 and to pH 8,4 at station No 8. With few exceptions, over the entire year there was a gradual lowering in pH from the surface to the bottom. The value of this decrease ranged from 0.01 to 0.10 units. The annual means of

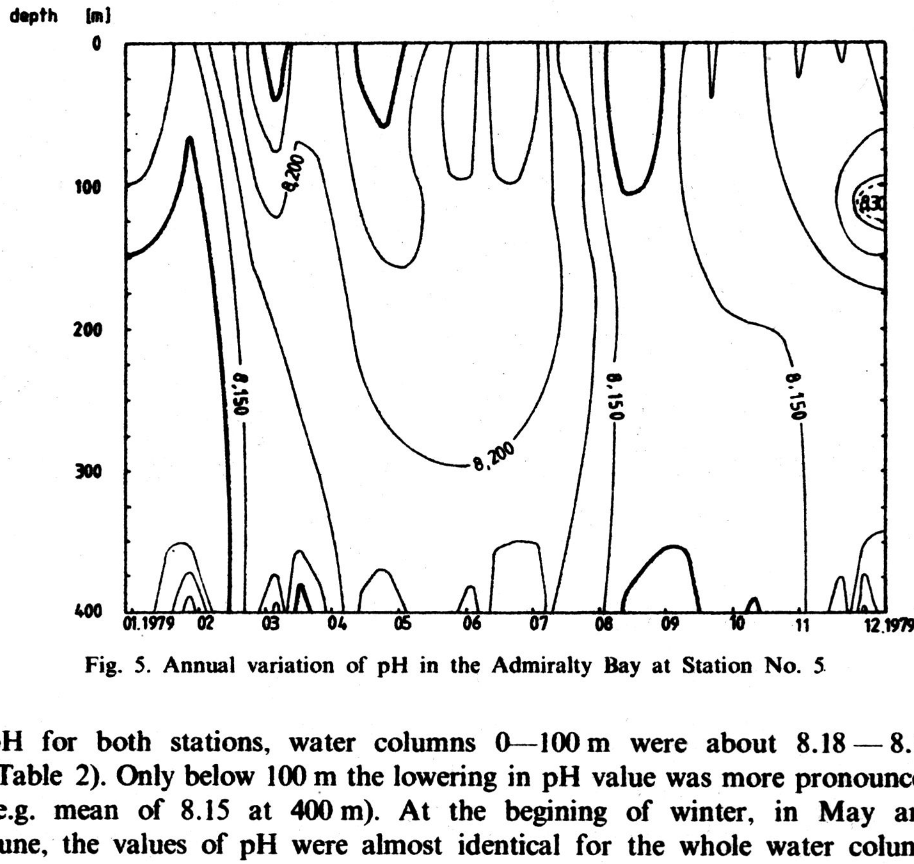

Fig. 5. Annual variation of pH in the Admiralty Bay at Station No. 5

pH for both stations, water columns 0—100 m were about 8.18 — 8.19 (Table 2). Only below 100 m the lowering in pH value was more pronounced (e.g. mean of 8.15 at 400 m). At the begining of winter, in May and June, the values of pH were almost identical for the whole water column considered.

7. Concentration of phosphates

Seasonal cycle of inorganic phosphates content showed a range of changes from about 1 to 2.6 µgat/dm^3 (excluding one measurement of 0.68 µgat/dm^3 at 400 m (Fig. 6). During summer a typical vertical structure was observed, i.e. an increase of phosphates concentration with greater depth. In May and June there was a uniform distribution of concentrations in the whole water column, which was followed by a change to a reversed distribution, that is lowering of concentrations with depth; this reversed distribution lasted to the end of the sampling period. Annual means (Tab. 2) calculated

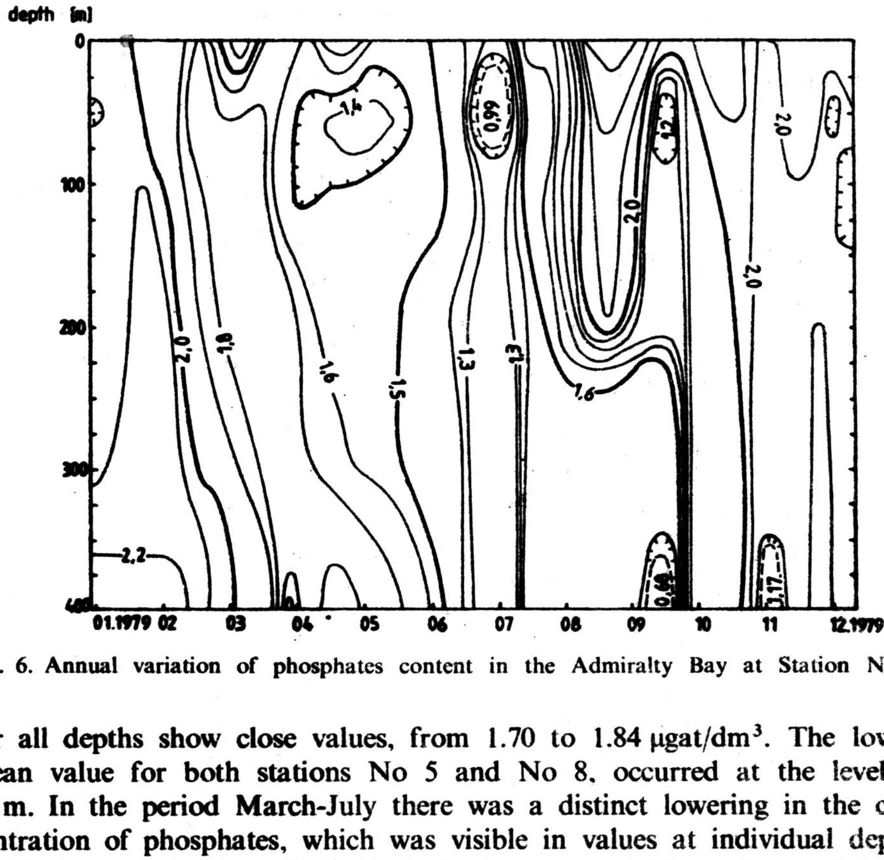

Fig. 6. Annual variation of phosphates content in the Admiralty Bay at Station No. 5

for all depths show close values, from 1.70 to 1.84 μgat/dm³. The lowest mean value for both stations No 5 and No 8, occurred at the level of 25 m. In the period March-July there was a distinct lowering in the concentration of phosphates, which was visible in values at individual depths and in integrated values (Tab. 3). In both oceanographic stations, minimum concentration values occurred several times between 25 and 100 m. During the whole year the phosphates content in the water of Admiralty Bay was high. In the euphotic zone and deeper down to 200 m the concentrations did not decrease below 0.96 μgat/dm³.

8. Concentration of dissolved silicates

Concentrations of dissolved silicates ranged from 73 μgat/dm³ in surface waters to 102 μgat/dm³ at 400 m depth (Fig. 7). Maximum surface concentrations reached the value of 90 μgat/dm³ (Tab. 2). During the entire year there was observed a continuous increase of silicates concentration with depth. The difference between surface values and that at 400 m fluctuated between ca 3 to 21 μgat/dm^3. In summer, changes in silicates content was substantial and was caused by an exchange of waters in the bay, as well as by the development of diatoms. This phenomenon was

Table 3

Admiralty Bay station No. 5. Integrated values (0—400 m depth) of some components of sea water

Sampling date	O_2 dm^3/dm^2	PO_4 mgat/dm^2	Si mgat/dm^2	NO_2 mgat/dm^2	NO_3 mgat/dm^2	chlor. a mg/m^2	Plant carot. mg/m^2
10.I.1979	27,39	8,24	359,4	0,24	71,92	63,87	14,00
25.I.	26,44	8,53	367,1	0,64	85,56	56,87	22,37
4.II.	25,66	8,36	358,8	0,74	78,54	75,50	31,25
15.II.	26,43	7,44	352,2	0,59	68,23	170,7	105,7
5.III.	23,91	7,20	363,2	1,02	124,2	104,5	17,0
16.III.	23,94	7,86	349,3	0,71	104,9	180,1	55,25
28.III.	24,75	5,85	338,3	0,78	119,2	117,1	13,75
9.IV.	25,64	6,82	315,6	0,84	114,9	70,0	19,37
18.IV.	26,14	6,07	364,0	0,85	127,5	51,50	12,62
7.V.	27,43	6,33	363,6	0,92	123,6	49,00	3,75
23.V.	28,02	6,43	354,2	1,17	125,2	58,13	11,00
1.VI.	29,60	5,67	357,8	1,20	123,0	56,38	3,38
10.VI.	28,90	5,62	349,6	1,17	120,8	49,25	7,88
29.VI.	29,01	4,91	360,9	0,86	130,2	46,75	9,25
10.VII.	30,17	5,83	344,7	0,81	129,9	36,50	4,13
25.VIII.	29,24	8,14	364,3	0,41	134,1	39,37	6,63
4.IX.	27,77	6,03	349,1	0,24	118,8	29,25	2,63
14.IX	27,68	6,15	354,8	0,07	127,9	59,25	4,00
23.IX.	27,56	7,76	360,6	0,30	131,5	52,50	19,12
8.X.	27,94	7,98	364,5	0,33	125,1	41,00	14,25
19.X.	28,55	7,96	366,9	0,77	122,9	47,62	5,75
29.X.	27,12	6,59	368,0	0,43	130,6	44,00	6,13
6.XI	28,83	7,65	375,1	—	129,6	41,75	3,38
18.XI.	28,97	8,01	366,1	1,12	126,2	88,12	42,37
26.XI.	29,24	7,19	353,0	0,84	113,7	11,9	26,50
4.XII.	27,36	7,92	368,4	0,42	123,1	129,9	38,00
Annual mean	26,46	7,02	357,3	0,70	121,0	71,95	19,21

easy to observe in the second half of March till the begining of April. In winter concentrations of silicates gradually increase with a simultaneous lowering of the vertical gradient. A second decrease in the content of silicates appeared in November and December, the period of first phytoplankton bloom. The integrated values, on the other hand, showed high

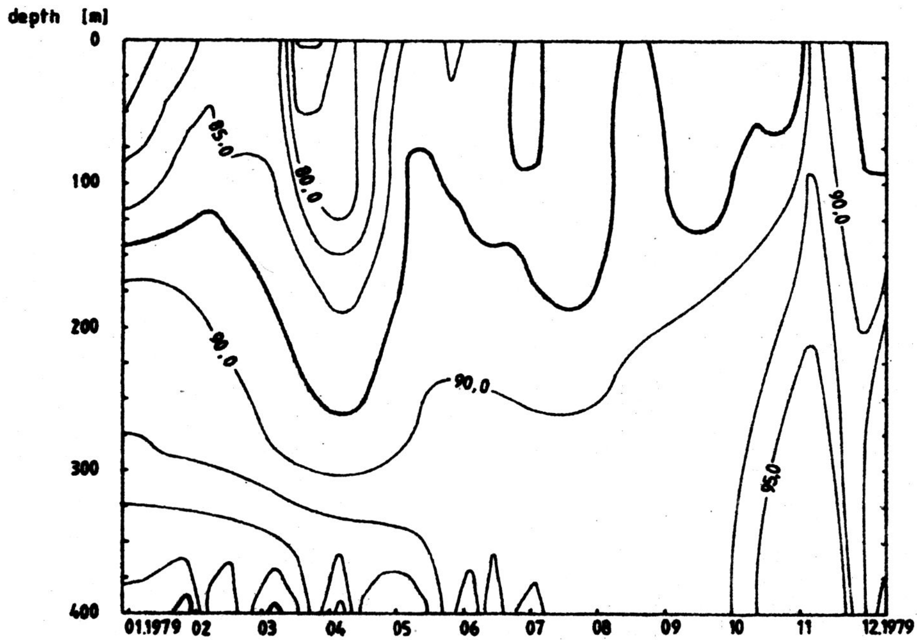

Fig. 7. Annual variation of silicates content in the Admiralty Bay at Station No. 5

stability, and with the exception of a decrease in silicates concentration in March and April, over the whole year they were close to the annual mean values (Tab. 3).

9. Concentration of nitrites

The observed concentrations of nitrites were low and fell within the range 0.01 — 0.60 µgat/dm^3 (Tab. 2, Fig. 8). Generally, the concentrations decreased with increasing depth, sometimes however, samples from 230 and 400 m showed much greater values. This phenomenon occurred only in the case when water sample was taken directly above the bottom (because of variable bottom configuration in the vicinity of oceanographic stations). In the cycle of seasonal variations, quite changeable contents of nitrites during summer increased considerable from the middle of April until June and then it decreased until the first blooms of phytoplankton when the concentrations rose again. High concentrations of nitrites at the onset of winter suggest that they are related to the bacterial processes of decomposition of organic matter.

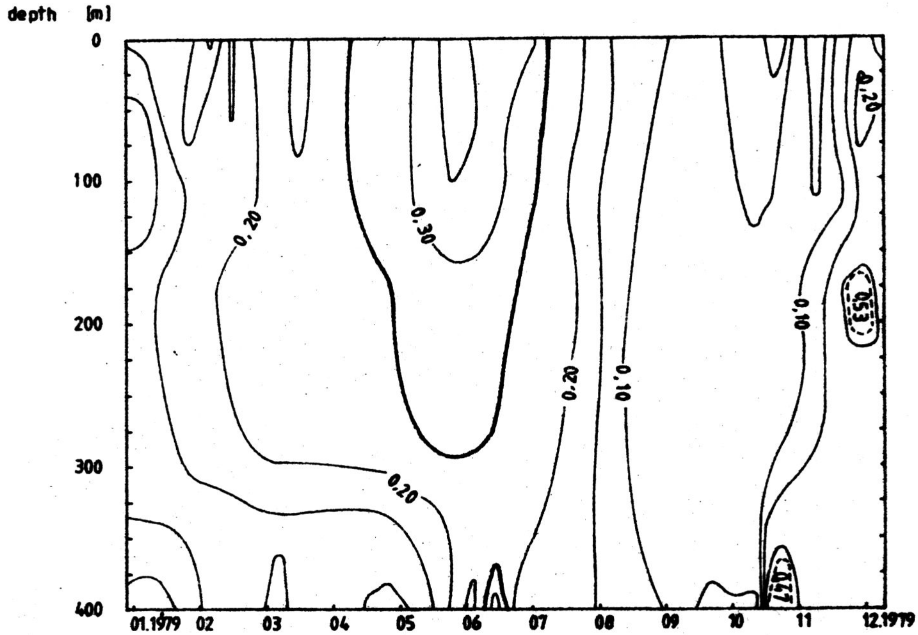

Fig. 8. Annual variation of nitrites content in the Admiralty Bay at Station No. 5

10. Concentrations of nitrates

Average concentrations of nitrates in Admiralty Bay were high and exceed at the surface the values of 30 μgat/dm^3 (Table 2, Fig. 9). Vertical distribution of nitrates contents was characterized by a gradual increase of concentrations with depth. In winter concentrations above bottom reached 33—34 μgat/dm^3. During summer very high, sixfold decreases of nitrate concentrations occurred in the euphotic zone which was strictly related to the period of phytoplankton development. During winter the quantities of nitrates gradually increased, especially at greater depths; this was probably the result of processes of microbiological decomposition of organic matter. This phenomenon was easy to observe in changes of integrated values (Tab. 3).

Among the most important forms of nutrients, the concentrations of nitrates in Admiralty Bay undergo the most pronounced changes as the effect of biological activity.

11. Chlorophyll *a* content

Variations in chlorophyll *a* content (calculated according to the equation of SCOR/UNESCO) in Admiralty Bay in 1979 are shown in Table 2

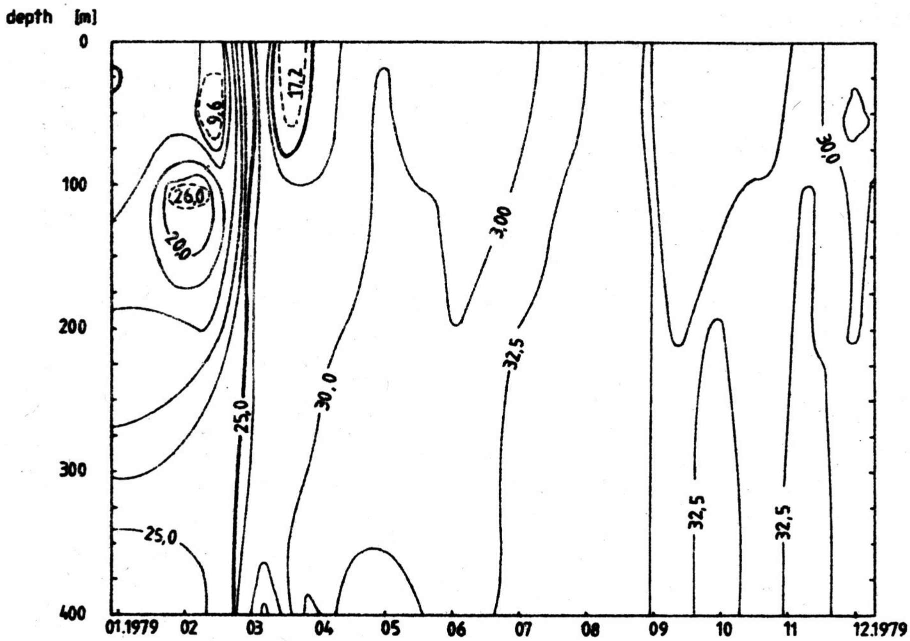

Fig. 9. Annual variation of nitrates content in the Admiralty Bay at Station No. 5

and Fig. 10. The first low concentrations, 0.3—0.4 mg/m^3 in the euphotic zone abruptly increased during summer blooms to 1.7—2.0 mg/m^3. Periods of high values observed in the middle of February and March were separated by period of a decrease of chlorophyll *a* content and a large scale exchange of waters in Admiralty Bay. In the first decade of April the quantity of chlorophyll *a* suddenly decreased in the surface waters reaching at the end of winter values below 0.1 mg/m^3. At that time no chlorophyll *a* could be detected at 400 m depth. The first distinct increases in chlorophyll occurred in November and in December. In the vertical distribution, substantial amounts of chlorophyll (0.2—0.3 mg/m^3) occurred down to 100 m, and sporadically to 200 or 230 m, thus at depths much exceeding the lower limit of euphotic zone. During summer (January—April), quite often maximal concentrations occurred at the depths of 25—50 m, while in November the highest values were found at 50—100 m.

Chlorophyll *a* distribution in Admiralty Bay is characterized by sudden changes of concentrations which correspond to the peaks and lows of phytoplankton development. During a phytoplankton bloom, chlorophyll concentrations exceeded several times the annual average value, but soon afterwards there followed a sudden lowering in the chlorophyll content. Quite often the decreases were caused by an exchange of waters between Admiralty Bay and the Bransfield Strait.

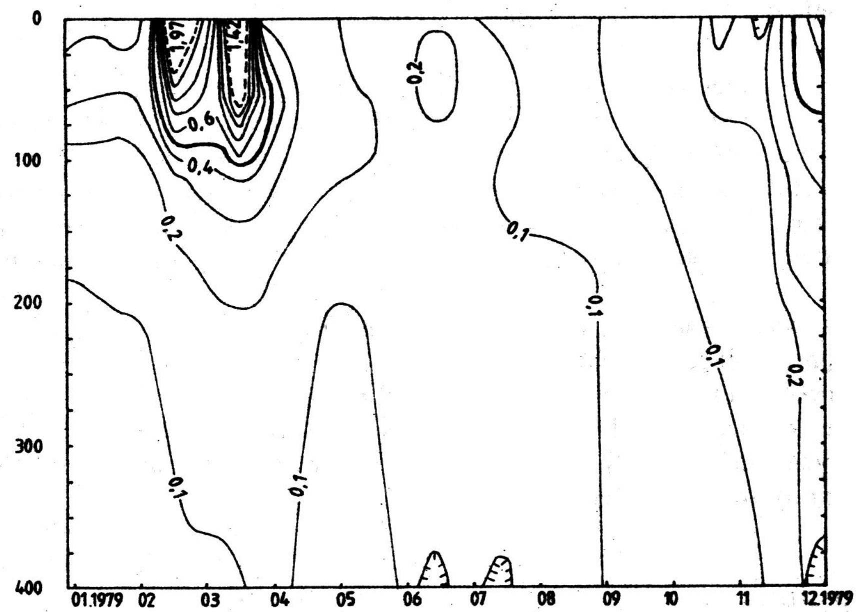

Fig. 10. Annual variation of chlorophyll a content in the Admiralty Bay at Station No. 5

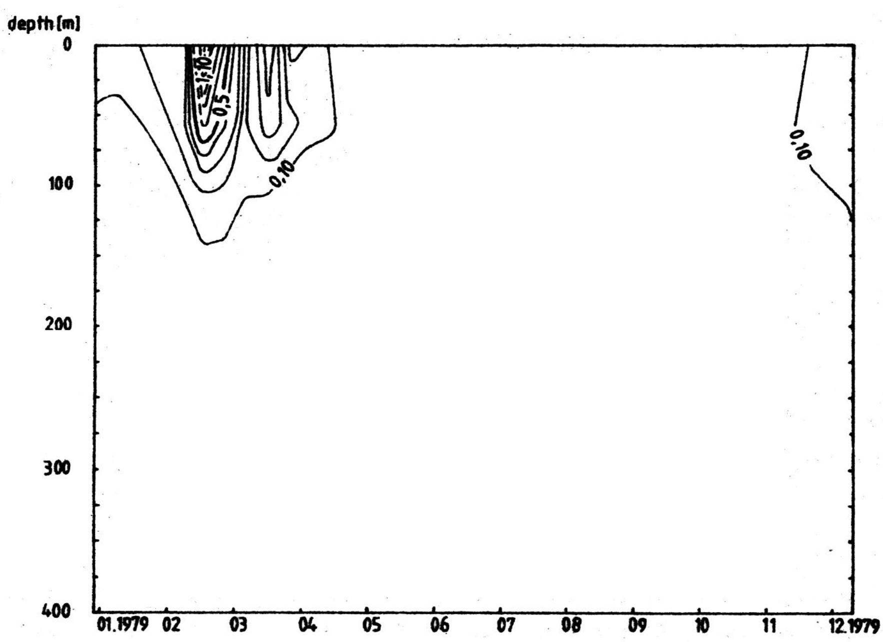

Fig. 11. Annual variation of plant carotenoids content in the Admiralty Bay at Station No. 5.

12. Content of plant carotenoids

Plant carotenoids were measured at the time of determination of chlorophyll *a*. Concentrations of carotenoids, both average and extreme values, were twice lower than those of chlorophyll *a* (Tab. 2, Fig. 11). Their vertical and seasonal distributions however, were very similar to those of chlorophyll. Because of low concentrations in winter, carotenoids were very often undetectable with the method used, in the entire column of water.

This was caused by the limited volume of water (up to six liters) used for filtering. The fact, that there was a strong correlation between the concentrations of chlorophyll *a* and carotenoids in the water column between surface and about 200 m shows, that the quantitative ratio of these pigments in the phytoplankton in Admiralty Bay did not change significantly during the entire year.

Discussion

In the analysis of the present results two problems seem to be of a foremost importance. The first is the determinations of the variations of the 10 parameteres which were measured. The second is the estimation, in what degree the local conditions of Admiralty Bay differentiate these waters from those above the shelf in the regions of the West Antarctic. T/S data allow us to state, that during the entire year of 1979, into the Admiralty Bay inflows of modified waters of the Bellingshausen Sea origin occurred. Seasonal changes of temperature in Admiralty Bay are typical for surface waters in the Antarctic and they occur indepedently of the fact, whether the sea is covered with ice (c.f. Krebs 1983) or not (Bienati and Comes 1970). It is very interesting, that the average annual temperatures for a water column between surface and 400 m were very much alike. This would indicate intensive processes of vertical mixing existing in Admiralty Bay.

The most interesting phenomenon for the seasonal variations in salinity, is the occurrence during summer of a distinct lowering of salinity values in a water column between surface and 50—75 m depth. It is the result of ice melting and fresh water runoff from land. The effects of local decreases in salinity of the order of several or even more than ten parts per thousand are evident only in a microscale in a surface layer of less than 10 meters, in a direct vicinity of water runoff from land. It can also be observed on a greater scale in the areas of straits and bays with a limited contact with the open sea. For example, the Paradise Harbour waters had the following annual average surface salinties: 1965 — 33.62‰

1967 — 33.72‰; 1968 — 33.82‰. In comparison, the annual average for Admiralty Bay in 1979 was 33.97‰.

To summarize the analysis of temperature and salinity data for Admiralty Bay, it can be stated that the central part of the bay down to the depth below 200 m, as well as Ezcurra Inlet, have during the entire year a rather uniform water mass which is characterized by a homogeneous TS structure. One should emphasize the very small vertical stability of waters in the bay. There is an absence of distinct thermoclines or picnoclines. Waters in the bay undergo further changes under the influence of tidal and wind generated currents. Winds and tides cause the phenomenon of nearshore upwellings, the vertical mixing of water and the exchange of waters with the Bransfield Strait.

Oxygenation of sea water depends on biological activity such as photosynthesis, respiration and oxidation of organic matter, and on physical phenomena. The data obtained on the oxygenation of Admiralty Bay waters show, that in the annual scale the oxygen content in the water is dependent mainly on the solubility of oxygen in sea water and also on the processes of mixing. The fact, that the physical processes dominate, seems to be the characteristic feature for the Antarctic waters at these latitudes. During phytoplankton development periods of oxygen oversaturation occur very rarely and the maximal values exceed only 2.5% the equilibrium state of oxygen saturation. A similar description of seasonal changes to that in Admiralty Bay is given for the Arthur Harbor (Palmer Archipelago) by Shabica, Hedgpeth and Park (1977). Other authors (Bunt 1960, Tressler and Ommundsen 1962, Littlepage 1965, Hoshiai 1969, Bienati and Comes 1970, Rakusa-Suszczewski 1972) who investigated the annual changes in dissolved oxygen content, did not observe a winter maximum, however they worked in basins covered in winter with ice. As suggested by Kanwisher (1963) high waves and breakers are the most important factors in the exchange of oxygen through the air-sea boundary. Thus, the occurrence of a consistent ice cover over wide ares of sea surface has a most important effect on the seasonal changes in oxygen content of Antarctic waters in the nearshore zone.

Biological factors have the greatest influence on the changes of pH in Antarctic waters. In the present work pH values were recalculated to values in situ, that is to the real pH values at the natural temperature of the water. This gave the observed range of values from 8.03 to 8.40. These changes are very small. The coefficient of variation for seasonal changes is only about 0.5%. A rise in pH was observed only once at the time of an intensive photosynthesis and simultaneous high stability of water in the bay. Much higher increases in pH and a better correlation between pH values and the quantity of chlorophyll can be observed in the water bodies where intensive vertical mixing of water does not occur, as for example, in more than a dozen meters water layer below ice cover (Hoshiai 1969). In Admiralty Bay, the high intensity of vertical mixing prevents any distinct local increases in pH, a natural phenomenon resulting from intensive processes of photosynthesis. Previous works on the annual changes in pH values in the Antarctic regions (Bunt 1970, Tressler and Ommundsen 1962, Littlepage 1965, Hoshiai 1969, Bienati, and Comes 1970, Shabica, Hedgpeth and Park 1977) include only very scanty information on the methods of measurements used by the authors. The wide range of results noted by them brings up the question whether they have used proper pH standards for calibration of their pH-meters. In addition to that, these authors seem to be ignoring the dependence of pH on temperature, since they do not state what temperatures correspond to the given values of pH.

The presented results from Admiralty Bay show that of the three major nutrients measured, only the concentrations of nitrates exibited a distinct cycle of an annual change and they were significantly correlated with the quantities of chlorophyll *a*. No explicit trends of seasonal changes were observed in the concentrations of phosphates; no decreases were noted during phytoplankton blooms either. Similarly, the concentrations of silicates which are indispensable for diatoms' growth, decreased only about 10% below the annual average value, during periods of phytoplankton blooms. Minimum values for the concentrations of nutrients in Admiralty Bay in 1979 are the following: PO_4 — 0.96 μgat/dm^3; Si — 73.1 μgat/dm^3; NO_3 — 5.7 μgat/dm^3. So far there are no data on the concentrations of nutrients which would be limiting for phytoplankton growth in the Antarctic waters. No experiments were done to determine the value of k constant which expresses the concentration of nutrient at which its uptake rate decreases to half of the maximal rate. For comparison: the values of k constant determined at higher temperatures (8—25°C) are: for nitrates 0.22 — 0.75 μgat/dm^3; phosphates 0.12 — 0.60 μgat/dm^3; silicates 0.8 — 3.77 μgat/dm^3 (after Heywood and Whitaker 1984). Assuming that these concentrations hold true also at the temperatures between -1.8 to $+2.0$°C, it is evident, that the concentrations of nutrients found in Admiralty Bay are in no way limiting for phytoplankton growth. There are relatively few works showing seasonal changes in nutrients concentrations in the Antarctic waters. Phosphates were determined by Bunt (1960), Littlepage (1965), Bienati and Comes (1970), Aržanova (1974), Tanner and Herbert (1981), and by Fukuchi, Tanimura and Ohtsuka (1985). Determinations of reactive silicates were done by: Littlepage (1965), Rakusa-Suszczewski (1972), Aržanova (1974), Fukuchi, Tanimura and Ohtsuka (1985), Krebs (1983). Nitrates were determined only by Tanner and Herbert (1981) and by Fukuchi, Tanimura and Ohtsuka (1985). All these works showed, that regardless of the geographical region of investigations, or of the specific local conditions, the concentrations of nutrients in the Antarctic waters are very high the whole year round. The observed fluctuations in nutrients' concentrations are usually explained by the authors as a result of changing hydrological conditions. In some cases reasonable decreases in concentrations of nutrients were noted during intensive blooms of phytoplankton. As stated by Heywood and Whitaker (1984), the minimum summer concentrations of nutrients in Antarctic waters are higher than the maximum winter concentrations recorded in waters at lower latitudes.

The annual cycle of variations in the concentrations of nutrients in waters of Admiralty Bay, as well as the annual cycles for other regions of the Antarctic (Bienati and Comes 1970, Littlepage 1965, Krebs 1983) are entirely different from the annual cycles observed in temperate and tropical seas. The basic difference is the continuous presence in the Antarctic of high concentrations of nutrients even during periods of mass phytoplankton growth. This phenomenon is being presently explained (Holm-Hansen 1983) as the result of water column instability, where the processes of mixing, advection and eddy diffusion cause a continuous replenishment of nutrients in the euphotic zone. This hypothesis holds for the waters of Admiralty Bay if one considers the vertical distributions of temperature and salinity observed in this area. It is supported further by the lack of any sharp changes in the contents of dissolved oxygen and nutrients.

In contrast to the physical and chemical parameters considered, so far exhibiting only slight seasonal changes, the underwater light, which provides energy for the processes of photosynthesis, undergoes radical changes in the Antarctic. Thus total darkness is observed in winter, below the southern polar circle, while values exceeding 1300 J/cm^2 of light energy daily are recorded in the Admiralty Bay (Woźniak, Hapter and Maj 1983). With three factors that reduce the underwater light in winter (i.e. short day, unfavourable angle of sun rays that reflect at the sea surface and ice cover) there is only one phenomenon which favourably affects the light conditions. It is more than ten-fold increase in water transparency during winter.

Concentrations of chlorophyll *a* are considered in this work as the measure of phytoplankton biomass in Admiralty Bay. The annual cycle of changes in chlorophyll *a* in 1979 is typical for the waters of the Southern Ocean (compare with Heywood and Whitaker 1984). The summer bloom observed at the begining of investigations in December 1978, ends in March 1979. The low stability of waters in the bay and the quick exchange of water with the Bransfield Strait cause rapid and sharp changes in the chlorophyll content during summer. The absence of ice cover during Antarctic winter 1979 had created more favourable light conditions for phytoplankton populations. It is especially evident in examining the integrated values (Tab. 3). The quantities of chlorophyll typical for winter months are only twice lower than the annual average value for a given depth, and five to eight times lower than the quantities encountered during summer. Considering the difficulties of chlorophyll *a* determinations at low concentrations (<0.1 mg/m^3), the winter values are perphaps somewhat overestimated, however, other authors (Bienati, Comes and Spiedo 1971) observed in winter even higher chlorophyll values in water bodies similar to Admiralty Bay. Another interesting result, which is evident from the annual average values of chlorophyll, is the fact that the highest values at both stations occurred at the depth of 25 m. This can be caused by two factors: intensive mixing processes in the subsurface water layer preventing any greater phytoplankton development, and during summer there might occur photoinhibition. The onset of a mass phytoplankton development at the end of November was observed as an increase of chlorophyll concentrations in the whole water column between surface and 100 m depth. At station 8 maximum concentrations were found often at this time in the 50—100 m stratum. The depth of the euphotic zone, estimated from the measurements of Secchi disc disappearance (10—13 m) occurred, based on calculations of Poole and Atkins (1929) at 27—35 m. This about threefold greater depth of occurrence of large quantities of chlorophyll compared to the lower limit of the euphotic zone (traditionally estimated as depth where 1% of incident light penetrates) is not exceptional. This confirms the suggestion of El Sayed and Turner (1977), Holm-Hansen et al. (1977) and El Sayed (1978). They agree in the opinion that in the Antarctic, in the situation when no direct measurements of the compensation depth are made, the depth of 0.1% of the incident light should be taken as the lower limit of the euphotic zone. This depth fluctuates between 40 and 200 m.

Data on seasonal variations in chlorophyll *a* content obtained by other authors show generally similar pattern, however, the total effects of all local environmental factors cause certain differences for each of the investigated areas. Bienati, Comes and Spiedo (1971) who worked in the area of Paradise Harbour, and Krebs (1974, 1983) working in the area of Arthur Harbour observed at the surface in summer maximal values of chlorophyll exceeding 20 mg/m^3. Their winter minima were not lower than 0.2 mg/m^3 at the surface. In the shallow Borge Bay (Signy I.) where the average depth is 16.5 m, the quantities of chlorophyll during phytoplankton blooms reached about 36 mg/m^3, and during winter not less than 0.1 mg/m^3 at the surface (Whitaker 1982).

In spite of the similar south latitude locations (Borge Bay at 60°42'S; Admiralty Bay at 62°08'S; Arthur Harbour at 64°49'S; Paradise Harbour at 64°53'S) and close values of oceanographical and hydrochemical parameters, the Admiralty Bay, compared with the three other bays, is characterized by about tenfold lower concentrations of chlorophyll during summer blooms, and two-three fold lower values in winter. The presented results for chlorophyll values are not just accidental. Investigations in the other bays were conducted during several years, also for the Admiralty Bay we have additional data from the season 1981/82 (Tokarczyk 1986). The differences in the amounts of chlorophyll in these various bays give us an idea about the importance of local hydrodynamic conditions on phytoplankton development.

Results of investigations given by Burkholder and Sieburth (1961), El Sayed (1968) and those of the FIBEX and SIBEX expeditions (Lipski 1982, 1985) indicate, that oceanographic data which are characteristic for larger areas of shelf waters in the Bransfield Strait and around the South Shetland Islands are similar to the data obtained for Admiralty Bay. Areas around Anvers Island (that is Arthur Harbour on the same island and Paradise Harbour in the Gerlache Strait) were long known for their exceptionally rich phytoplankton. Morphological features of Admiralty Bay are responsible for the occurrence of various oceanographical phenomena which are typical for coastal waters. To these belong the fiord-like circulation generated by tides, nearshore upwelling and wind driven currents. At the same time, the large area of the bay and the deep and widely open connection with the Bransfield Strait prevent the formation and acumulation of any distinct local changes in physical or chemical parameters. This characteristic feature of Admiralty Bay allow us to treat the values of oceanographical parameters measured there as typical for shelf waters in these regions of the Antarctic.

6. References

Aržanova N. V. 1974. Raspredelenie, meždugodovye i sezonnye izmenenija soderžanija biogennyh elementov v More Skotia. — Trudy, VNIRO, 98: 77—90.

Bendschneider K., and Robinson R. J. 1952. A new spectrophotometric method for the determination of nitrite in sea water. — J. Mar. Res., 11: 87—96.

Bienati N. L., and Comes R. A. 1970. Variacion estacional de la composicion fisico-quimica del aqua de mar en Puerto Paraiso, Antartica Occidental. — Contrib. Inst. Antart. Argentino, 130; 45 pp.

Bienati N. L., Comes R. A. and Spiedo C. H. 1971. Variacion estacional de pigmentos fotosinteticos en aquas Antarticas. — Contr. Inst. Antar. Argentino, 109; 22 pp.

Bunt J. S. 1960. Introductory studies: Hydrology and plankton, Mawson (June 1956 — February 1957). — ANARE Reports, Ser. B, III; 135 pp.

Burkholder P. B. and Sieburth J. M. 1961. Phytoplankton and chlorophyll in the Gerlache and Bransfield Straits of Antarctica. — Limnol. Oceanogr., 6: 45—52.

Catewicz Z. 1983. Variability of water flow in the Ezcurra Inlet. — Oceanologia, 15: 75—95.

Catewicz Z. and Kowalik Z. 1983. Harmonic analysis of tides in Admiralty Bay. — Oceanologia, 15: 97—109.

Čikovskij S. S. 1969. Pribrežnye gidrologičeskie issledovanija v more Dejvisa v 1965/66 g. — Trudy SAE, 49: 346—354.

Edler L. 1979. Recommendations on methods for marine biological studies in the Baltic Sea, Phytoplankton and chlorophyll. — The Baltic Marine Biologists Publ., 5; 38 pp.

El Sayed S. Z. 1968. On the productivity of the southwest Atlantic Ocean and the water west of the Antarctic Peninsula. — Ant. Res., 11: 15—47.

El Sayed S. Z. 1978. Primary productivity and estimates of potential yields of Southern Ocean. In: M. A. McWhinnie (ed.); Polar research to the present and the future. — AAAS Selected Symposium 7, Westview Press Inc., USA; 141—160.

El Sayed S. Z. and Turner J. T. 1977. Productivity of the Antarctic and tropical/sub-tropical regions: a comparative study. In: M. J. Dunber (ed.); Polar Oceans; 463—501.

FAO Fisheries Technical Paper No 137. Manual of methods in aquatic environment research. Part 1. Methods for detection, measurement and monitoring of water pollution. — Rome 1975; 238 pp.

Fedak K. and Marsz A. (in press). Podstawowe cechy morfometryczne i morfologiczne Zatoki Admiralicji na Wyspie Króla Jerzego w Archipelagu Szetlandów Południowych.

Fukuchi M., Tanimura A. and Ohtsuka H. 1985. Marine biological and oceanographical investigations in Lutzow-Holm Bay, Antarctica. In: W. R. Siegfried, P. R. Condy, R. M. Laws (eds.); Antarctic nutrient cycles and food webs. — Springer Verlag; 52—59.

Grasshoff K. 1964. On the determination of silica in sea water. — Deep-Sea Res., 11: 597—604.

Grasshoff K. 1976. Methods of seawater analysis. — Verlag Chemie,

Harvey H. W. 1960. The chemistry and fertility of sea waters. — London, 240 pp.

Hedgpeth J. W. 1977. The Antarctic Marine Ecosystem. In: G. A. Llano (ed.); Adaptation within Antarctic Ecosystem; 3—10.

Heywood R. B. and Whitaker T. M. 1984. The Antarctic marine flora. In: R. M. Laws (ed.); Antarctic Ecology, Vol. 2. — Academic Press, London; 373—419.

Holm-Hansen O. 1983. Marine nutrient cycles. Proc. of Fourth SCAR Symposium on Antarctic Biology: 1—17.

Holm-Hansen O. 1977. Primary production and the factors controlling phytoplankton growth in the Southern Ocean. In: G. A. Llano (ed.); Adaptation within Antarctic Ecosystem; 11—50.

Hoshiai T. 1969. Seasonal variation of chlorophyll *a* and hydrological conditions under sea ice at Syowa Station, Anarctica. — Antarctic Record, 35: 52—67.

International Oceanographic Tables, Vol. 2. — National Institute of Oceanography of Great Britain and UNESCO, 1973.

Jerlov N. G. 1976. Marine optics. — Elsevier, Amsterdam; 231 pp.

Kanwisher J. 1963. On the exchange of gases between the atmosphere and the sea. — Deep-Sea Res., 10: 195—207.

Krebs W. N. 1974. Physical-chemical oceanography of Arthur Harbour, Anvers Island. — Ant. J. US, 9: 219—221.

Krebs W. N. 1983. Ecology of neritic marine diatoms, Arthur Harbour, Antarctica. — Micropaleontology, 29: 267—297.

Lafond E. C. and Lafond K. G. 1971. Oceanography and its relation to marine organic production. In: J. D. Costlow (ed.); Fertility of the sea; 241—265.

Lipski M. 1982. The distribution of chlorophyll *a* in relation to the water masses in the southern Drake Passage and the Bransfield Strait (BIOMASS-FIBEX, February-March 1981). — Pol. Polar Res., 3: 143—152.

Lipski M. 1985. Chlorophyll *a* in the Bransfield Strait and in the southern part of Drake

Passage during BIOMASS-SIBEX (December 1983 — January 1984). — Pol. Polar Res., 6: 21—30.

Littlepage J. L. 1965. Oceanographic investigations in McMurdo Sound, Antarctica. In: G. A. Llando (ed.); Biology of Antarctic Seas II. — Ant. Res. Ser. 5: 1—37.

Lorenzen C. J. 1967. Determination of chlorophyll and pheopigments: Spectrophotometric equations. — Limnol. Oceanogr., 12: 343—346.

Marsz A. and Rakusa-Suszczewski S. (in press). Charakterystyka warunków fizyko-geograficznych rejonu Zatoki Admiralicji (Wyspa Króla Jerzego, Szetlandy Południowe). — Kosmos, 35.

Murphy J. and Riley J. P. 1962. A modified single solution method for the determination of phosphate in natural waters. — Anal. Chim. Acta, 27: 31—36.

Pęcherzewski K. 1980. Distribution and quantity of suspended matter in Admiralty Bay (King George Island, South Shetland Islands). — Pol. Polar Res., 1: 75—82.

Poole H. H. and Atkins W. R. G. 1929. Photoelectric measurements of submarine illumination throughout the year. — J. Mar. Biol. Ass. U. K. N. S., 16: 297—324.

Pruszak Z. 1980. Currents circulation in the waters of Admiralty Bay (region of Arctowski Station on King George Island). — Pol. Polar Res., 1: 55—74.

Rakusa-Suszczewski S. 1972. Winter hydrological observations in Alasheyev Bight, Eastern Antarctic. — Pol. Arch. Hydrobiol., 19: 1—9.

Rakusa-Suszczewski S. 1980. The role of near-shore research in gainning an understanding of the functioning of Antarctic ecosystem. — Pol. Arch. Hydrobiol., 27: 229—233.

Riemann B. 1978. Carotenoid interference in the spectrophotometric determination of chlorophyll degradation products from natural population of phytoplankton. — Limnol. Oceanogr., 23: 1059—1066.

Samp R. 1980. Selected environmental factors in the waters of Admiralty Bay (King George Island, South Shetland Islands), December 1978 — February 1979. — Pol. Polar Res., 1: 53—66.

Shabica S. V., Hedgpeth J. W. and Park P. K. 1977. Dissolved oxygen and pH increases by primary production in surface water of Arthur Harbour, Antarctica, 1970—1971. In: G. A. Llano (ed.); Adaptations within Antarctic ecosystems; 83—97.

Stramski D. and Montwiłł K. 1982. Light conditions in the Antarctic waters of the Drake Passage and the South Shetland Islands region during summer 1981. — Pol. Polar Res., 3: 153—170.

Strickland J. D. H. and Parsons T. R. 1968. A practical handbook of sea water analysis. — Bull. Fish. Res. Board. Can., 167: 341 pp.

Szafrański Z. and Lipski M. 1982. Characteristics of water temperature and salinity at Admiralty Bay (King George Island, South Shetland Islands, Antarctica) during the austral summer 1978/1979. — Pol. Polar Res., 3: 7—24.

Tanner A. C. and Herbert R. A. 1981. Nutrient regeneration in maritime Antarctic sediments. — Kieler Meeresforsch. Sonderh., 5: 390—395.

Tokarczyk R. 1986. Annual cycle of chlorophyll *a* in Admiralty Bay 1981—1982 (King George Island, South Shetland Islands). — Pol. Arch. Hydrobiol., 33: 177—188.

Tolstoy A. 1977. Methods of determining chlorophyll *a* in phytoplankton. — Naturvards. Limnol. Unders. Rapp., 91; 62 pp.

Tressler W. L. and Ommundsen A. M. 1962. Seasonal oceanographic studies in McMurdo Sound, Antarctica. — US Navy Hydrogr. Office Techn. Rep., 125; 141 pp.

Wensierski W. and Woźniak B. 1978. Optical properties of water in Antarctic waters. — Pol. Arch. Hydrobiol., 25: 517—533.

Whitaker T. M. 1982. Primary production of phytoplankton of Signy Island, South Orkneys, Antarctica. — Proc. R. Soc. London B 214; 169—189

Woźniak B., Hapter R. and Maj B. 1983. The inflow of solar energy and the irradiance of the euphotic zone in the region of Ezcurra Inlet during the Antarctic summer of 1977/78. — Oceanologia, 15: 141—173.

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7. Streszczenie

W roku 1979 na dwóch głównych stacjach oceanicznych, usytuowanych w Zatoce Admiralicji (Wyspa Króla Jerzego, Szetlandy Południowe; Tab. 1, Rys. 1) pobrano 54 próby wody morskiej z głębokości 0, 25, 50, 100, 200 i 400 m. Określono sezonową zmienność 10 parametrów — temperatury, zasolenia, pH, zawartości tlenu, fosforanów, reaktywnej krzemionki, azotynów, azotanów, chlorofilu „a" i karotenoidów roślinnych (Rys. 2—11). Wartości średnie badanych parametrów oraz podstawowe obliczenia statystyczne dla Stacji Nr 5 przedstawia Tabela 2. Ponadto w Tabeli 3 zestawiono wartości integrowane niektórych składników wody morskiej na tej stacji oceanograficznej. Stwierdzono brak występowania wyraźnie zaznaczonych termoklin czy haloklin, co jest powodem bardzo małej stabilności wody w Zatoce. Zawartość nutrientów jest wysoka w ciągu całego roku i nie limituje rozwoju fitoplanktonu. Jedynie zawartość azotanów obniża się znacznie podczas letnich zakwitów. Mała stabilność wody oraz silne prądy występujące w Zatoce ograniczają maksymalne stężenie chlorofilu „a" do ok. 2 mg/m^3. Oceanograficzne, hydrochemiczne i hydrobiologiczne warunki występujące w Zatoce Admiralicji są typowe dla antarktycznych wód szelfowych w tym rejonie geograficznym.