POLISH POLAR RESEARCH (POL. POLAR RES). POLSKIE BADANIA POLARNE	1	4	43—52	1980

Jacek URBAŃSKI, Ewa NEUGEBAUER, Ryszard SPACJER
and Lucyna FALKOWSKA

Institute of Oceanography, University of Gdańsk, Gdynia

Physico-chemical characteristic of the waters of Hornsund Fjord on south-west Spitsbergen (Svalbard Archipelago) in the summer season 1979

ABSTRACT: Measurements of water temperatures, salinity, oxygen, suspended matter, nutrients and some metals contents were determined in the waters of the Hornsund Fjord. The investigations were carried out at the end of June and July and in mid-September 1979.

Key words: Arctic, Svalbard, physico-chemical characteristic of water

1. Introduction

The aim of the studies were physico-chemical investigations of the waters of Hornsund Fjord, situated southwards of Spitsbergen (Fig. 1). The fjord extends for about 30 km and its width varies from 6 to 8 km. The maximum depth is about 250 m.

Hornsund is under the influence of a complex system of water masses due to the proximity of the contact zone of the waters of the East-Spitsbergen and West-Spitsbergen Currents (Łomniewski, Zaleski and Żmudziński 1979).

The East-Spitsbergen Current flows southwards along the east coast of Spitsbergen. Salinity of the water surface in the area eastwards of Spitsbergen i.e. in the area under the effect of the current is in the summer season lower than $34^0/_{00}$ and water temperature corresponds to the thermal conditions in the upper layers of the Arctic waters (Coachman and Aagaard 1974). The West-Spitsbergen Current flows northwards along the west coast of Spitsbergen. Its waters are characterized generally by temperatures of about 3°C and salinity of about $35^0/_{00}$ (Coachman and Aagaard 1974).

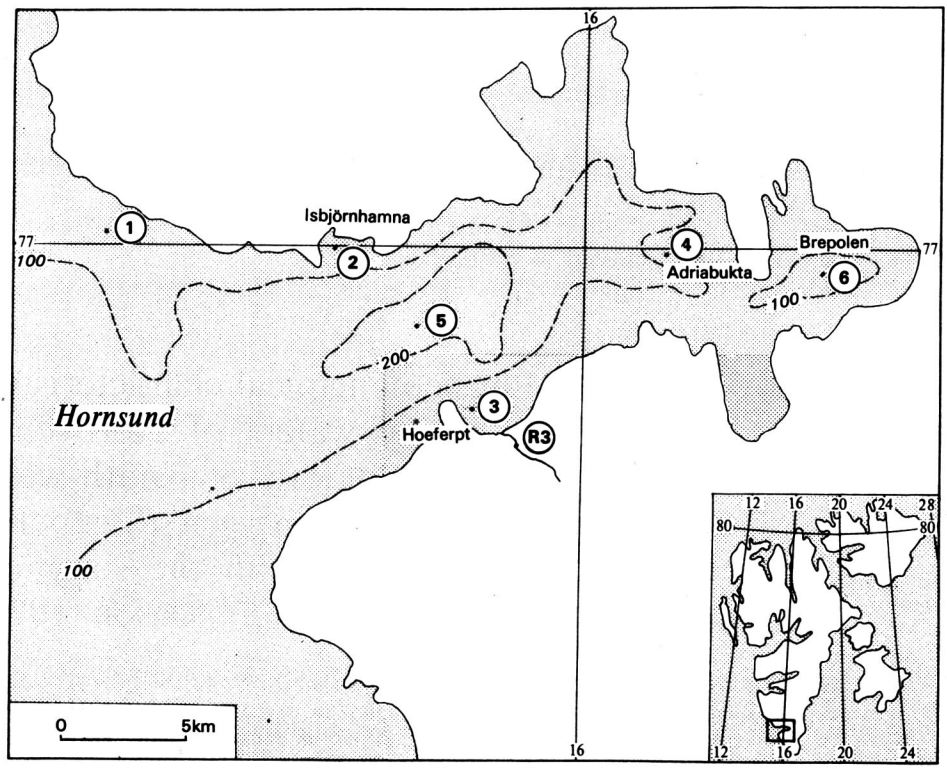

Fig. 1. Location of sampling stations in the Hornsund Fjord (Spitsbergen)
Numbers in circles market out the station.

Hydrological investigations in the Hornsund Fjord carried out hitherto by Polish scientific groups covered merely the measurements of temperature, salinity, oxygen content in shallow bays of Isbjörnhamna and Ariebukta and tidal phenomena (Swerpel 1976, Siwecki and Swerpel 1979).

2. Methods and materials

Measurements of water temperature, salinity, the contents of oxygen dissolved in water, suspended matter, nutrients (nitrites, ammonia, phosphates, silicon) and metals (copper, nickel, cadmium, lead, zinc) were carried out. The temperature was mesured down to the depth of 80 m with a temperature sounding — apparatus ETM-2 and below that depth with reversible thermometres. Salinity was determined with the Knudsen-Mohr method and oxygen content with the Winkler method. The quantity of suspended matter was determined by weight on the 0.45 μm dia. pores Whattman filters (Pęcherzewski 1978). Nutrients were determined spectrophotometrically (Grasshoff 1976). The content of metals was determined using the techniques of atom-absorping spectrophotometry (Thomas and Gibb 1975).

Measurements were conducted at six sampling stations in the fjord (Fig. 1), during three periods: 27—29 June, 30 July and 17—18 September 1979. In June, all the measurements were made at the stations Nos. 1, 2, 3, 4 and 5: in July, only the measurements of temperature and salinity were made at the station No. 6: in September, the temperature, salinity and the quantities of suspended matter and metals were determined at the stations Nos. 2, 3 and 5.

3. Results and discussion

The measurements of temperature and salinity in the waters of the fjord showed great variability in time and space. In June, in the whole mass of the fjord waters water temperatures below freezing point were observed lowering slightly with the increasing depth (Fig. 2). Salinity values exceeded 34.5‰

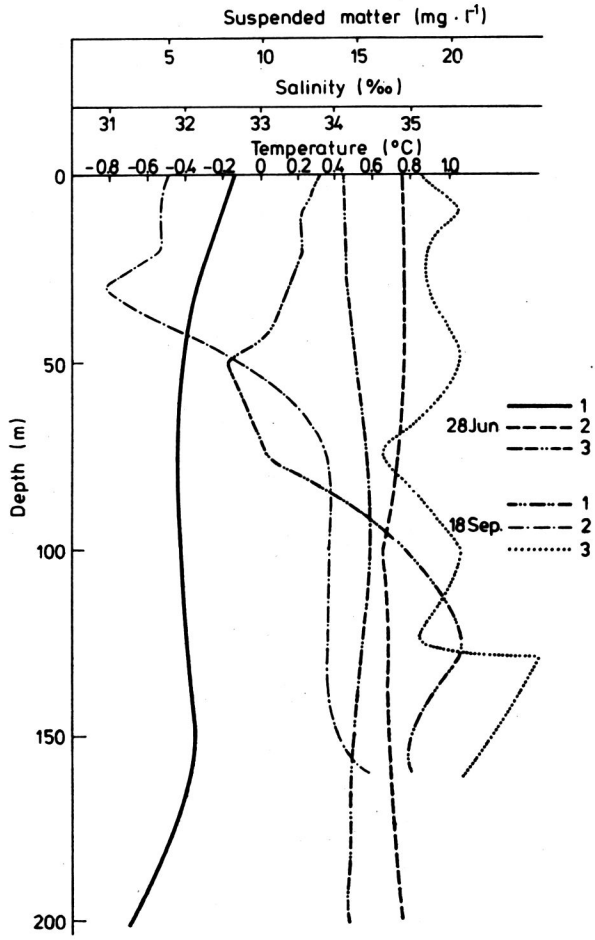

Fig. 2. Temperature (1), salinity (2) and suspended matter (3) in the waters of the Hornsund Fjord (station No. 5)

below the depth of 10 m deep and were less than $34^0/_{00}$ above the depth of 10 m deep, only in shallow bays. The salinity of water over $34.5^0/_{00}$ indicates genetic connection of these waters with the waters of the West-Spitsbergen Current (Coachman and Aagaard 1974). Lowering of water temperature as compared with the mean temperatures of the West-Spitsbergen Current might occur in result of a strong cooling of the waters in the fjord area in the wintertime. At the end of the summer, during the September measurements, in almost the whole mass of the fjord waters temperatures, above freezing point were noted. At the station No. 5, salinity was increasing from the water surface to the depth of 80 m deep, reaching the value of $34^0/_{00}$, deeper downwards salinity values did not change, practically (Fig. 2). Temperatures below freezing point occurred only in the several meter wide water-layer at the depth of about 50 m deep.

This is in all probability an intermediate layer (dichothermal layer) which is a characteristic feature of the surface layers of Arctic waters in the shelf areas during the summer. The occurrence of an intermediate cool water layer comes in effect of the warming up of the upper layers of the surface Arctic waters (Zubov 1945).

A specific situation was observed in July, at the station No. 6. The measurements were taken several days after the permanent ice-cover moved away from the bay. Temperature and salinity distribution showed great variability (Fig. 3). The occurrence of a layer of water at the bottom showing very low temperature (-1.9 °C) and salinity coming up to $34.9^0/_{00}$ is a very characteristic feature. This was very likely due to the remainder of very cold and strongly saline water left over from the winter-spring season.

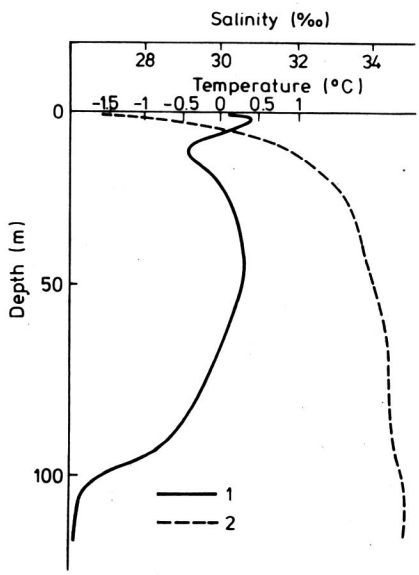

Fig. 3. Temperature (1), salinity (2) of the water in the Hornsund Fjord (station No. 6) on 30 July 1979

Higher upwards the temperature of the water rises up to above 0°C at the depth of 60 m and salinity decreases gradually to $33^0/_{00}$ at the depth of 20 m and $27^0/_{00}$ at the water surface. At the depth of 10 m and at the water surface two layers of temperature inversion were observed. The occurrence of such water layers in the Hornsund Fjord was already described (Siwecki and Swerpel 1979). The occurrence of the inversive layer at the depth of 5—10 m is caused by the warming up of water surface by streams, sun radiation and turbulent heat exchange between the water and the air. Maybe that it is also due in some part to the underlying warmer water of Atlantic provenance. The layer at the water surface is formed probably by streams from glaciers with the temperature approaching freezing point.

Spatial variability, due to a small number of sampling stations, was distinctly marked only in comparison with the hydrology of shallow bays and the open waters of the fjord. In the bays lower salinity was observed and higher vertically gradients of temperature and salinity. This was caused by chute of water from glaciers and streams.

The distribution of the temperature and salinity in the Isbjörnhamna shallow glacial bay follows a specific course at the sampling station No. 2 (Fig. 4). During the measurements carried out in June water temperatures were below freezing point. The most characteristic feature in the distribution of temperatures was the occurrence of a water layer, about 7 m wide, showing the lowest temperature. A strong stratification of salinity was observed in

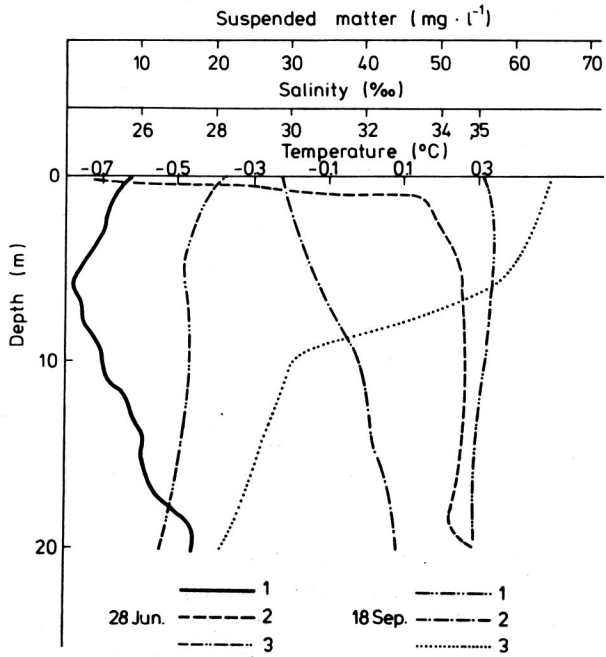

Fig. 4. Temperature (1), salinity (2) and suspended matter (3) in the waters of the Hornsund Fjord (station No. 2)

the bay. At the surface of the bay salinity was $24^0/_{00}$, increasing rapidly downwards up to nearly $34^0/_{00}$ at the depth of 2 m deep. In September salinity stratification was less distinctly marked but this might have been caused by a strong mixing of the waters by the wind during the time of the measurements.

The measurements carried out in June showed saturation of water with oxygen ranging from 36% to 109%. A relatively high saturation of water with oxygen was noted in the foreground of the fjord — at the station No. 1 over 94% throughout the vertical section from the surface to the bottom and at the station No. 5 over 85% to the depth of 50 m deep (Fig. 5).

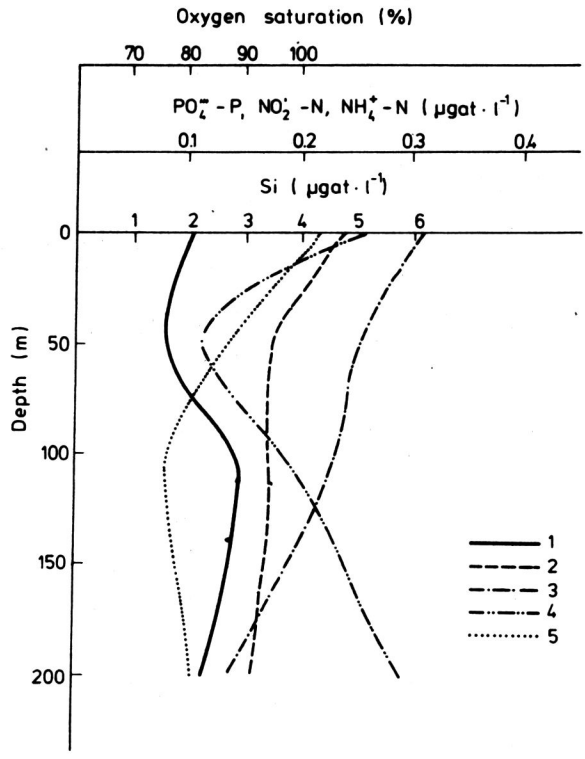

Fig. 5. Saturation of water with oxygen and concentration of nutrients in the waters of the Hornsund Fjord (station No. 5) on 28 June 1979
1 — PO_4''' – P, 2 — NO_2' – N, 3 — NH_4^+ – N, 4 — Si, 5 — O_2.

At the remaining stations lower values were recorded. In the shallow bays the maximum saturation of water with oxygen was 72% (station No. 2, Fig. 6) and 60% (station No. 3), the minimum values were 58% and 46% respectively. The lowest saturation value — 36% was noted at the station No. 4, at the depth of 50 m. The values of oxygen dissolved in water are rather unexpected. Maybe it was due to the fact that measurements were made shortly after the permanent ice-cover drifted away from the fjord.

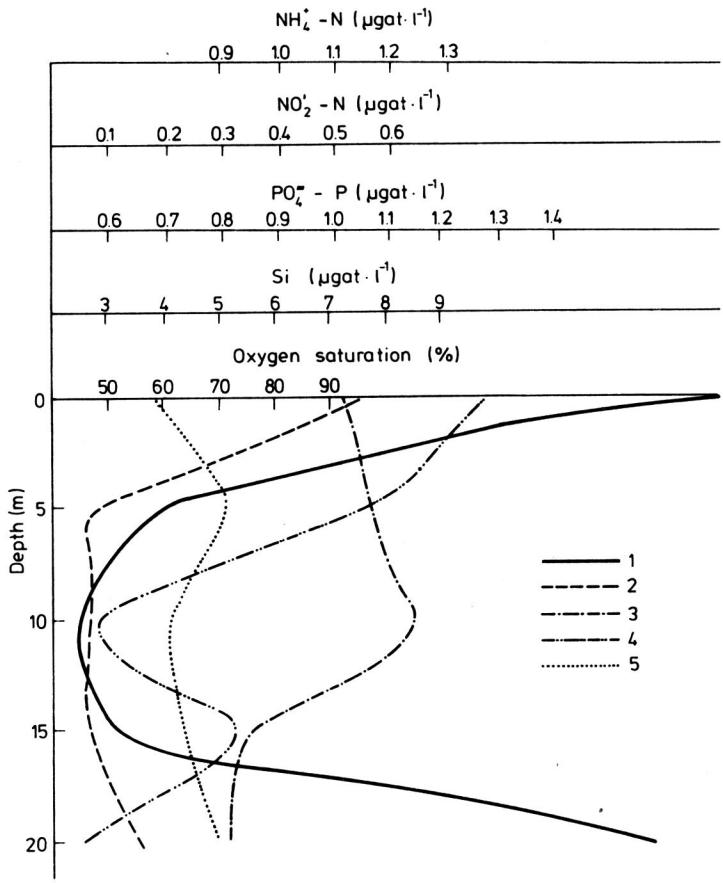

Fig. 6. Oxygen saturation and concentration of nutrients in the waters of the Hornsund Fjord (station No. 2) on 28 June 1979
Explanations see Fig. 5.

In June quantities of suspended matter ranged from 21 mg·l^{-1} at the surface of the Isbjörnhamna Bay (station No. 2, Fig. 4) to 11 mg·l^{-1} in the foreground of the fjord (station No. 1). At all the stations stratification was insignificant. The water of the stream contained great quantities of suspended matter. The quantity of suspended matter in the water of the stream falling into Goshamna Bay (station No. R3) was 56 mg·l^{-1}. In September much higher quantities of suspended matter were recorded. In the Isbjörnhamna Bay (station No. 2, Fig. 4) the quantity of suspended matter at the water surface was up to 65 mg·l^{-1}. At the remaining stations the content of suspended matter ranged from 26 to 16 mg·l^{-1}. Well-marked increase in the quantity of suspended matter in September, as compared with the results from the measurements carried out in June, is a sign of seasonal changes in the quantity of suspended matter. It occurs in all probability in consequence of the seasonal chutes of water from the land.

Mean concentrations of inorganic nitrogen, inorganic phosphorus and

silicon in the open waters of the fjord were at the time of measurements: mitrites 0.1 μgat $NO_2' - N \cdot l^{-1}$, ammonium 0.35 μgat $NH_4^+ - N \cdot l^{-1}$, phosphates 0.3 μgat $PO_4''' - P \cdot l^{-1}$, silicon 5 μgat $Si \cdot l^{-1}$.

In the coastal zone higher concentration of nutrients was observed. It was caused by supply of these compounds by streams and runoffs from the land. The concentration of nutrients in the river falling into the Goshamna Bay (station No. R3) was as follows: nitrites 0.62 $\mu gat \cdot l^{-1}$, ammonia 1.96 $\mu gat \cdot l^{-1}$, phosphates 1.51 $\mu gat \cdot l^{-1}$, silicon 46 $\mu gat \cdot l^{-1}$. In the Isbjörnhamna Bay (station No. 2, Fig. 6) a well-marked vertical stratification of the content of these substances was observed. The surface water layers are richer in nutrients than those below the depths of 5 m. At the bottom an increase in the content of nutritive substances, except ammonia and silicon compounds, is noted again. In the waters of the fjord at the station No. 5 (Fig. 5) only insignificant fluctuations in the concentration of these compounds were observed in the vertical cross-section.

The average concentrations of the determined metals were at all the stations in the range of: lead — 0.06—1.15 ppb, cadmium — 0.04—0.13 ppb, zink — 8.2—16.8 ppb, copper 0.6—2.5 ppb, and nickel — 0.6—0.8 ppb. Only insignificant fluctuations in the vertical distribution of the content of all the determined metals were observed as well in June as in September.

4. Summary

In the summer 1979, measurements of the temperature, salinity and oxygen, suspended matter, nutrients and metals content in water were carried out in the Hornsund Fjord. Great differences in the distribution of temperature and salinity were found within the different periods of the measurements.

In June, there was no distinct stratification in the vertical distribution of salinity (Figs. 2 and 4). Salinity of the waters below the depth of 10 m downwards was over $34.5^0/_{00}$. Water temperatures throughout the fjord were below freezing point (Figs. 2 and 4). In September, water temperatures above freezing point were noted in nearly the whole mass of the fjord waters (Figs. 2 and 4). Temperatures below freezing point were observed only in a several meter-wide water-layer at the depth of about 50 m deep (Fig. 2).

The measurements of oxygen content carried out in June gave unexpected results. Saturation of water with oxygen ranged from 36% to 109% (Figs. 5 and 6). The distribution of suspended matter showed great variability in time and space. The greatest quantities of suspended matter were found in the shallow glacial bays averaging at the water surface up to 65 $mg \cdot l^{-1}$ (Fig. 4).

5. Резюме

Летом 1979 года проведено в фиорде Хорнсунд измерения температуры, солёности а также содержания кислорода, взвеси, биогенических солей и металлей в воде. В расмещении температуры и солённости констатировано большое разницы в отдельных измерительных периодах: В июне не было чёткой стратификации солёности вод. Солёность воды ниже 10 м глубины переходила $34{,}5^\circ/_{\circ\circ}$. Температура воды во всём фиорде была отрцательной (рис. 2 и 4). В сентябре почти во всей массе вод фиорда наблюдались положительные температуры (рис. 2 и 4). Отрицательные температуры

выступали только в слое вод больше десяти метров на глубине около 50 м (рис. 2). Неожиданные результаты дали измерения содержания кислорода, которые проведено в июне. Насыщение кислорода изменялось с 36 % до 109% в зависимости от глубины и расположения измерительного пункта (рис. 5 и 6). Размещение взвеси указывало на большую переменчивость так во времении как и в пространстве. Больше всего завешенной материи было в неглубоких заливах, где отмечено на поверхности величины до 65 мг·л$^{-1}$ (рис. 4).

6. Streszczenie

Latem 1979 roku wykonano w fiordzie Hornsund pomiary temperatury, zasolenia oraz zawartości tlenu, zawiesiny, soli biogenicznych i metali zawartych w wodzie. W rozkładzie temperatury i zasolenia stwierdzono duże różnice w poszczególnych okresach pomiarowych. W czerwcu brak było wyraźnej stratyfikacji zasolenia wód (rys. 2 i 4). Zasolenie wody poniżej 10 m głębokości przekraczało 34,5‰. Temperatura wody w całym fiordzie była ujemna (rys. 2 i 4). We wrześniu, w prawie całej masie wód fiordu obserwowano temperatury dodatnie (rys. 2 i 4). Temperatury ujemne występowały tylko w kilkunasto-metrowej warstwie wody na głębokości około 50 m (rys. 2). Niespodziewane wyniki dały pomiary zawartości tlenu, które przeprowadzono w czerwcu. Nasycenie wody tlenem wahało się od 36% do 109% (rys. 5 i 6). Rozkład zawiesiny wykazywał dużą zmienność zarówno w czasie jak i w przestrzeni. Najwięcej materii zawieszonej było w płytkich zatokach lodowcowych, gdzie notowano na powierzchni wartości od 65 mg·l^{-1} (rys. 4).

7. References

1. Coachman L. K., Aagaard K. 1974 — Marine geology and oceanography of the Arctic Seas — Berlin, New York, 395 pp.
2. Grasshoff K. 1976 — Methods of seawater analysis — Verlag Chemie, Weinheim-New York, 317 pp.
3. Łomniewski K., Zaleski J., Żmudziński L. 1979 — Morze Arktyczne — Warszawa, 476 pp.
4. Pęcherzewski K. 1978 — Distribution of suspended matter and organic carbon in Antarctic Waters — Pol. Arch. Hydrobiol. 25: 561—571.
5. Siwecki R., Swerpel S. 1979 — Badania oceanograficzne w fiordzie Hornsund w latach 1974—1975 — Zesz. nauk. Wydz. Biologii i Nauk o Ziemi Uniwersytetu Gdańskiego — Oceanografia, 6: 46—58.
6. Swerpel S. 1976 — Badania hydrologiczne przybrzeżnych akwenów w fiordzie Hornsund latem 1975 roku — Biul. Polar. 1976 — Wrocław, 20—31.
7. Thomas R. D., Gibb J. 1975 — Analytical methods in oceanography — Tufts University, American Chemical Society, Washington, 238 pp.
8. Zubov N. N. 1945 — L'dy Arktiki — Moskva, 359 p.p.

Paper received 24 January 1980

AUTHORS' ADDRESSES:

Mgr Jacek Urbański
Mgr inż. Ewa Neugebauer
Mgr Ryszard Spacjer
Mgr Lucyna Falkowska

Instytut Oceanografii
Uniwersytetu Gdańskiego
Czołgistów 46
81-378 Gdynia, Poland