POLISH POLAR RESEARCH	9	1	121—132	1988

Eduard J. SARUKHANYAN[1] and Ryszard TOKARCZYK[2]

[1] Department of Polex-South
Arctic and Antarctic Scientific Research Institute
Fontanki 34
192104 Leningrad, USSR

[2] Department of Polar Research
Institute of Ecology
Polish Academy of Sciences
Dziekanów Leśny
05-092 Łomianki, POLAND

Coarse-scale hydrological conditions in Admiralty Bay, King George Island, West Antarctica, summer 1982

ABSTRACT: Net of temperature, salinity and dissolved oxygen content measurements were made *in situ* at 24 stations in Admiralty Bay with the use of automatic analyzer Martek MK IV. Results proved a presence of two water masses located horizontally one over the other, with the boundary at depth of 15—35 m. The main, lower mass consists of homogenous waters inflowing from the Bransfield Strait. The upper, thin and much differentiated layer is formed through interaction of the main underlying water mass with meltwaters from glaciers and sea ice. It is probably formed along the whole archipelago and carried by surface currents into the bay where it is subjected to further modifications. Local salinity and temperature extremes are associated with glacier water runoff; local dissolved oxygen maxima seem to be connected with phytoplankton distribution. Strong currents occurring in te bay due to water circulation may cause local, short term and sometimes considerable fluctuations in values of parameters recorded at individual stations.

Key words: Antarctica, South Shetland Islands, hydrology.

Introduction

The Admiralty Bay is a branched fjord, penetrating deeply into southern shores of King George (Waterloo) Island. At the outlet to the Bransfield Strait it is about 6 km wide. In the central part is up to 500 m deep

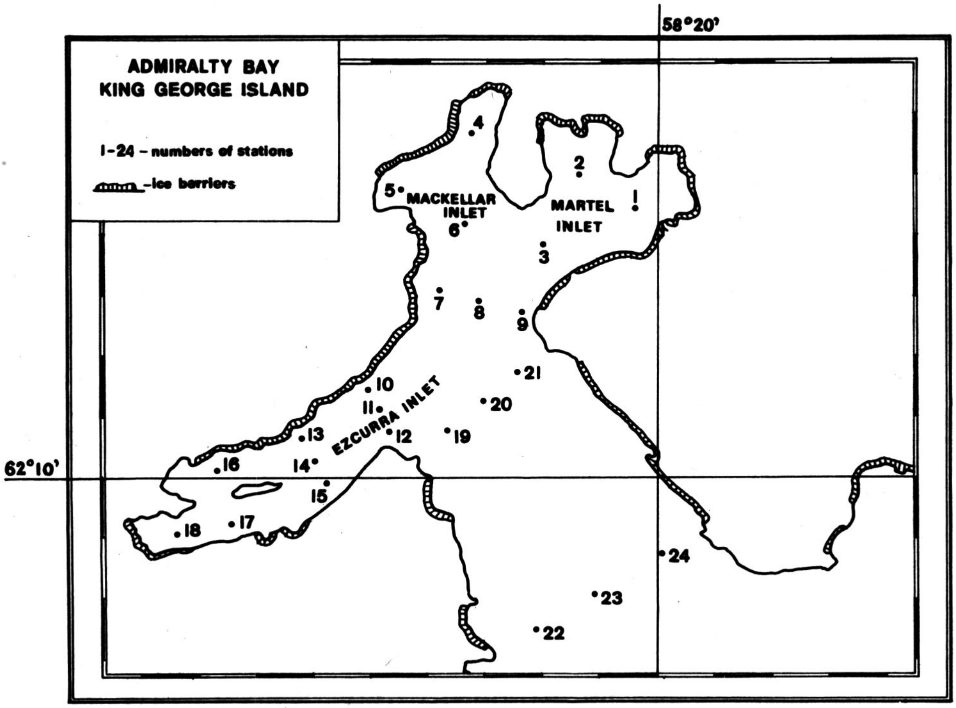

Fig. 1. Oceanographic stations in Admiralty Bay (King George Island) in austral summer 1982

(Rakusa-Suszczewski 1980). Hydrological conditions in the bay are determined by exchange of waters with the Bransfield Strait (Rakusa-Suszczewski 1980), runoff of fresh inland water (Pęcherzewski 1980) and local processes characteristic for fjords (Wright 1971). Water exchange between the bay and the Bransfield Strait is estimated (Pruszak 1980) to occur in every 1—2 weeks. Tides act as the decisive factor in this exchange (Rakusa-Suszczewski 1980). They are irregular (Wróbel 1977) and change direction of water movement every 5 to 14 hours. Velocity of generated currents is estimated for 30—50 cm/s at depths of 50—100 m (Pruszak 1980). Amplitudes of these currents reach their maximum for 24 h periods (Catewicz 1984); lower values were observed for 12, 8, and 4 h periods. Surface currents generated mainly by wind are much more variable and their velocities reach 20 cm/s close to the shores and 100 cm/s in the central part of the bay (Pruszak 1980). Glacier water runoff has not been calculated precisely but it is significant enough in summer to change water salinity in fjords (Rakusa-Suszczewski 1980, Szafrański and Lipski 1982). The quantity of suspended matter brought along with glacial waters may reach 200 tons/day (Pęcherzewski 1980). In summer, water temperature and salinity vary from −1.6°C to 3°C and from 16.4 to 34.1 at the surface, and from −0.3°C to 0.3°C and from 34.4 to 34.6 near the bottom (Szafrański and Lipski

1982). The lowest temperatures and salinities are observed in a narrow zone near glaciers. Dissolved oxygen content observed in waters of the bay in summer may locally exceed 10 cm^3/dcm^3 but generally remain within the range of 7.0—8.4 near the surface and falls to 5.8 near the bottom (Samp 1980). Diurnal changes in physical and chemical parameters (T, S, O_2, nutrients) in Ezcurra Inlet (Bojanowski 1984) depend mainly on periodical, semi-diurnal tidal cycle and reflect presence of two different water masses. Most waters that fill the bay, come from the Bransfield Strait (Rakusa-Suszczewski 1980, Pruszak 1980). The upper water layer, several to several dozen meters thick, consists of waters of lower salinity and dissolved oxygen content what probably reflects the effect of glacier water inflow (Bojanowski 1984). Depending on tidal phase, a transition between these water types is observed at various depths; in the center of the Ezcurra Inlet it occurs usually at depths between 15 m and 40 m (Bojanowski 1984). In summer 1982 temperature, salinity, and dissolved oxygen contents were registered for 2 days over the whole bay with Martek MK IV automatic analyzer, and diurnal variation of these parameters was studied at 4 selected oceanographic stations (Fig. 1). This study was supposed to supply with a full, possibly synopthic hydrologic picture, and to determine whether presence of the modified upper water layer is either restricted to secondary bays or is typical for the whole bay.

This study was supported by the Polish Academy of Sciences (Research Project MR.I.29).

Material and methods

Taking advantage of relatively fair weather, a set of temperature, salinity and dissolved oxygen content measurements were taken *in situ* from 24 stations in the Admiralty Bay on February 2 and 3, 1982. Measurements were taken with an automatic water quality analyzer Martek MK IV installed on a fishing boat „*Słoń Morski*". Sensors were calibrated directly before and after the measurements. Temperature sensor was calibrated against a reversal thermometer (GOHLA-Kiel), salinity sensor against standard sea water 35.000‰ and dissolved oxygen sensor after the Winkler method. The instrument permitted a continuous registration of discussed parameters at depths from 0.5 to 200 m, or 10 m above the echo-sounded bottom (Krupp Atlas Echograph 480; 100 kHz). Differentiation of the main water masses present in the bay and determination of their range were based on analyses of temperature and salinity. In order to estimate short-term fluctuations of measured parameters which could superimpose the obtained hydrologic picture, temperature, salinity and dissolved oxygen were measured during 24 h at selected stations (nos. 3, 8, 11, 14 — see: Fig. 1) on February 5 and 6. Measurements were taken

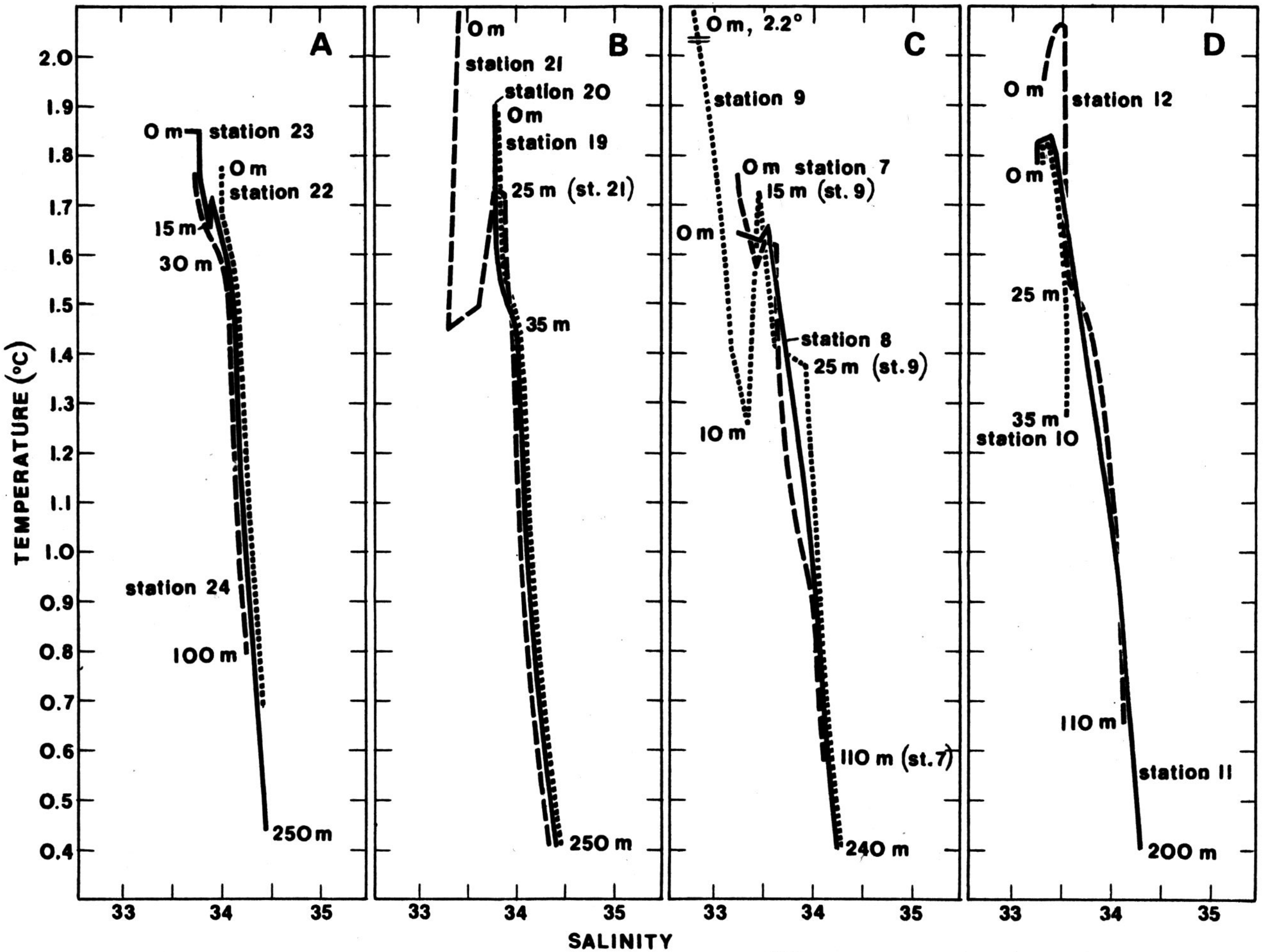

Fig. 2. Temperature — salinity diagrams for selected profiles in Admiralty Bay: A — mouth of the bay (stations: 22—24), B — central part of the bay (stations: 19—21), C — mouths of Martel and Mackellar Inlets (stations: 7—9), D — mouth of Ezcurra Inlet (stations: 10—12)

at successive stations every 1 hour, and between consecutive measurement series at the same station every 4 h. Then results were synchronized for the same moment by interpolation. Additionally short-term currents could be observed along a selected section. Their velocities were estimated on the basis of T—S measurements (Pond and Pickard 1978).

Results

On T—S diagrams (Fig. 2) there are two water masses located horizontally one above the other. A boundary between them, determined by changing slope of T—S curve (Fig. 2), occurs at depth of 15—35 m depth. The main body of water below consists of waters coming from the Bransfield Strait, and filling the bay at depths from several dozen meters to the bottom. Pattern of their characteristic T—S curves is practically identical at all stations, testifying that these waters are very homogenous. Neither thermocline nor halocline can be found to 250 m depth, whereas gradual decrease in temperature and dissolved oxygen content connected with increased salinity, suggest that clear seasonal division does not take place there.

The second water mass forms a thin layer, much more differentiated and spreading near the surface. It originates at contact of waters inflowing from the Bransfield Strait with the ice barrier which forms over a half of the bay coastline (Figs. 3—5). As compared to the underlying waters,

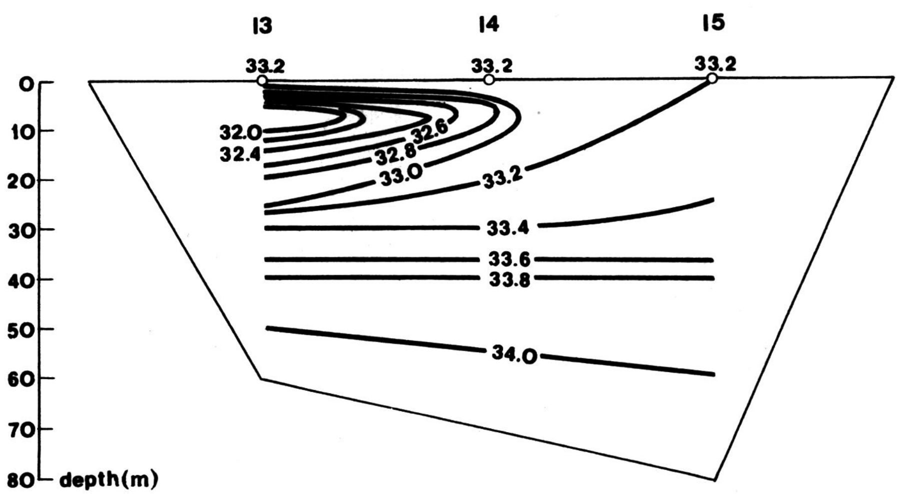

Fig. 3. Vertical distribution of salinity (practical scale) in Ezcurra Inlet (stations: 13—15)

lower salinity and increased dissolved oxygen content are characteristic here. Frequently encountered local temperature minimum (thermocline) is observed

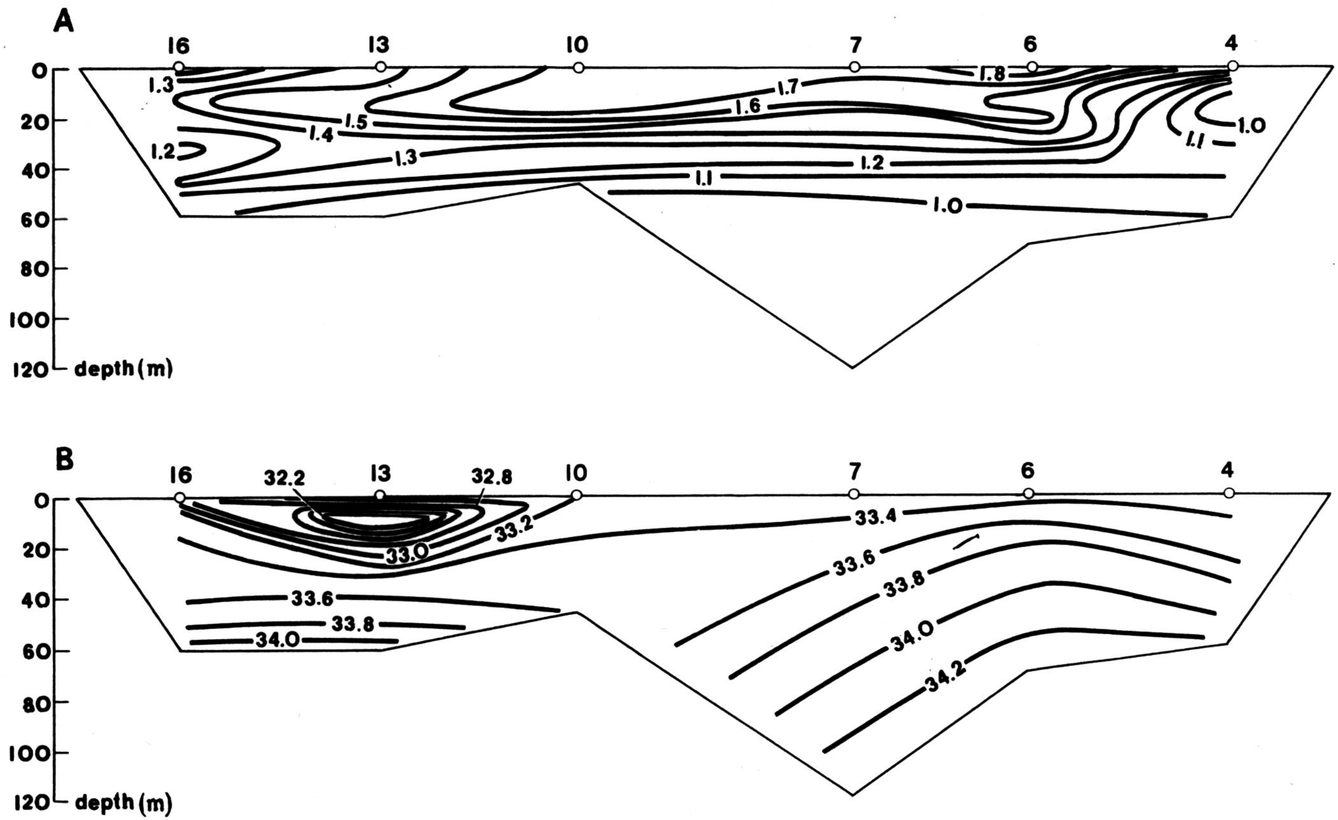

Fig. 4. Vertical distribution of temperature in °C (A) and salinity in (practical scale) (B) at stations positioned along the ice barrier (stations: 4, 6, 7, 10, 13 and 16)

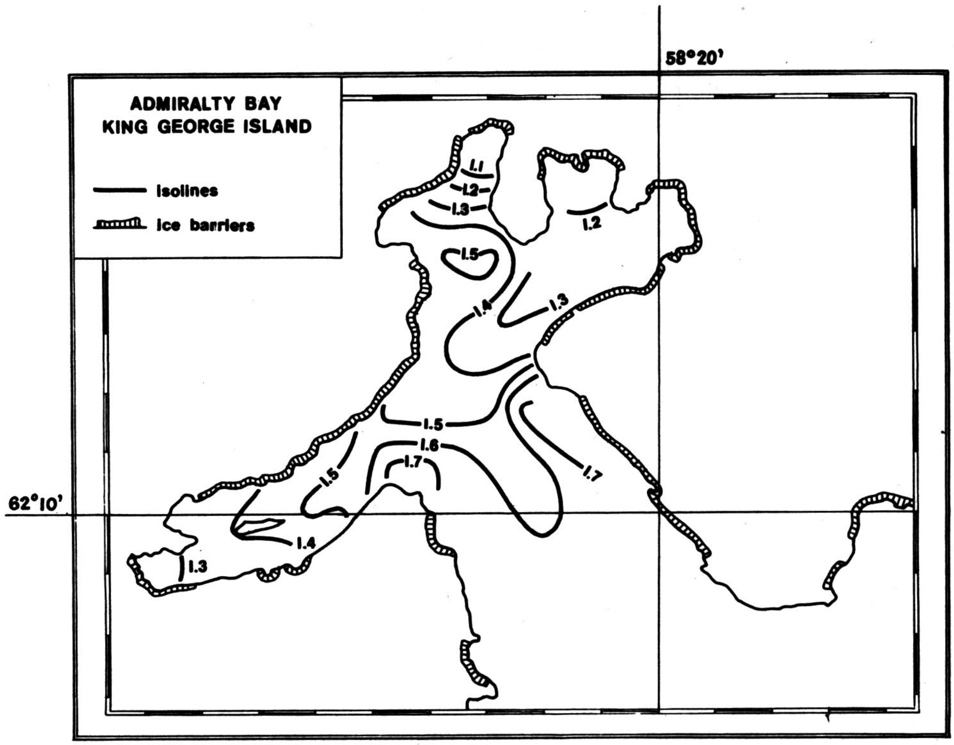

Fig. 5. Horizontal distribution of temperature (°C) at depth of 25 m

usually at depths of 1—10 m. Salinity minimum occurs less requently. It is well marked only near ice barriers (stations 13 and 14 — see: Figs. 3—4) and occurs as a rule slightly above (1—2 m) the observed local temperature minimum. Dissolved oxygen content in this water mass varies from 7.0 to 9.2 cm^3/dm^3. The highest values were observed in the Ezcurra Inlet (>8 cm^3/dm^3) and the lowest in Martel and Mackellar inlets. Distribution of dissolved oxygen content in the depth function is there not monotonous but occurrence of local maxima, sometimes two on one curve, is characteristic (Fig. 6). These maxima occur usually at depth of 10 m. At 1—4 m and 15 m they are encountered relatively often while less frequently at depth of 20 m. Influence of ice barriers is not restricted to a modification of salinity caused by fresh water runoff (Figs. 3—4), but also has a considerable effect on temperature (Figs. 4—5). Such phenomenon can be clearly observed in distribution of temperatures recorded at depth of 25 m (Fig. 5), *i.e.* beneath the range of local temperature changes caused by different insolation of various fragments of water (below the depth of thermocline occurrence). The lowest temperatures are observed in Mackellar and Martel inlets (1.1°—1.2°C) where glaciers form most of coastline. Slightly higher (1.3°—1.4°C) temperatures are noted inside the Ezcurra Inlet. The warmest waters are located in central parts of the bay (1.6°—1.7°C).

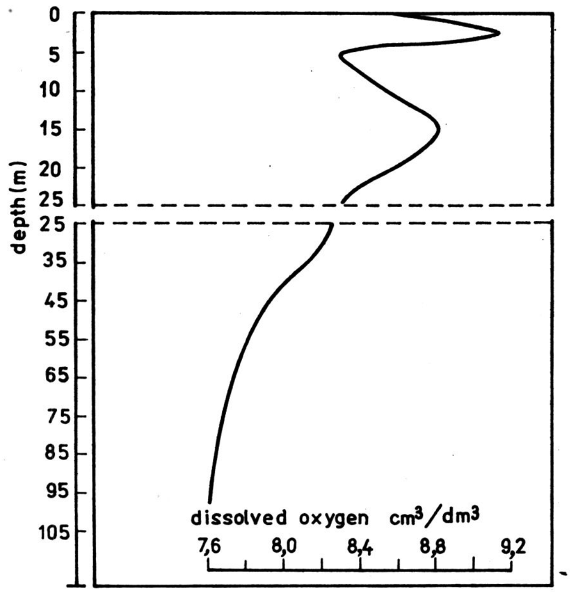

Fig. 6. Typical distribution of dissolved oxygen content in the function of depth; broken line separates distinguished water masses (February 3, 1982; station no. 12, sea floor 120 m, sea state 1)

As far as microstructure is concerned, diurnal observations of temperature, salinity and dissolved oxygen content suggest that values of these parameters fluctuate significantly in relatively short periods of time (several hours). Near the surface maximum changes were noted for salinity (+/−1) while below mainly for dissolved oxygen content (+/−0.5 cm^3/dm^3) and temperature (+/−0.3°C). Maximum oscillations are observed in the Ezcurra Inlet and the lowest in the center of the bay. Salinity distribution among stations 3, 8, 11 and 14, synchronised at 1 PM of local time (Fig. 7a), indicates an occurrence of a strong current. Isohaline pattern is typical for upwelling. A horizontal component of the current velocity vector, estimated from values of temperature and salinity, reaches its maximum (about 60 cm/s) at the surface between stations 8 and 11, and runs towards a mouth of the bay. After about 12 h (Fig. 7b) a direction of the current is reversed and its maximum velocity (about 80 cm/s) is noted between stations 11 and 14.

Discussion

Distinguished water masses were encountered in fjords in summer 1978 (Bojanowski 1984) and 1979 (Szafrański and Lipski 1982). During investigations in the Ezcurra Inlet (close to station 14 — see: Fig. 1) Bojanowski (1984) noted occurrence of these water masses for about 3 months and located

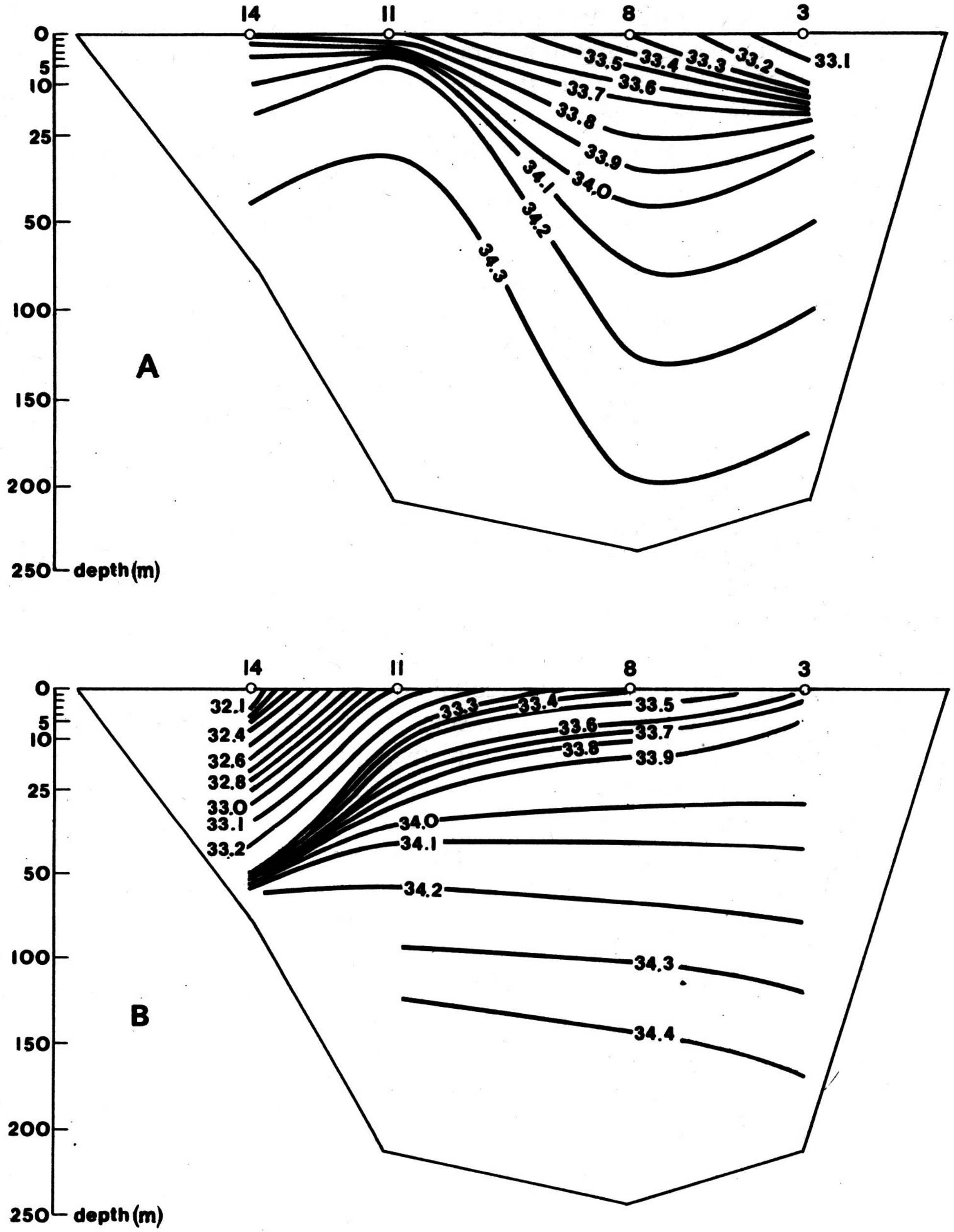

Fig. 7. Salinity distribution (practical scale) between stations 3, 8, 11 and 14 synchronized at 01.00 PM (A) and 01.00 AM (B) of local time (February 6, 1982).

a boundary between them at depth of 15—40 m. Szafrański and Lipski (1982) studied temperature and salinity of waters in the bay and observed a considerable influence of glacial waters on registered parameters. It stretched to depth of 25—40 m close to the ice barrier. In the open, central part of the bay no significant temperature and salinity gradients were observed. Absence of seasonal thermo- and haloclines (Szafrański and Lipski 1982) indicated thorough mixing of waters in these regions and put in doubt the occurrence of a separate surface layer. On the other hand, 25 m of distance between sampling levels did not allow for detailed estimation of changes near the surface. Studies in summer 1982 proved that a thin surface layer which had been observed earlier, was not restricted to zones of shallow Ezcurra, Martel, and Mackellar inlets but occurred in the whole bay (Figs. 2, 4). Most certainly it forms a layer of the so-called summer modification which originates from interaction of main water body with meltwaters from glaciers and sea ice. Its presence at stations 22—24 (Fig. 2a), directly near the Bransfield Strait suggests that it may not necessarily be restricted to the bay. Probably it is formed in consequence of discussed processes along the whole South Shetland Islands archipelago and is carried by surface currents into the Admiralty Bay where cooling and dilution is continued (Figs. 3—5). Mixing processes render impossible a formation of sharp, seasonal thermo- and halocline which should be expected in a closed basin. Continuous data record showed some interesting details in surface layer microstructure, *e.g.* sites of intense discharge of waters from ice barrier which are invisible from the surface (Fig. 3), or occurrence of local maxima of dissolved oxygen content (Fig. 6). Presence of the latter seems to be associated with primary production. Studies in the Ezcurra Inlet (Kopczyńska 1980) proved a presence at these depths of local maxima in phytoplankton concentration, mainly flagellates and "monads".

Studies of the variability of registered parameters along the Martel Inlet — Ezcurra Inlet section suggest that temperature, salinity, and dissolved oxygen content can change significantly in 24 hours. Data synchronised at one point in time indicate that these changes are associated with a local upwelling, the presence of which was anticipated by Rakusa-Suszczewski (1980) and Pruszak (1980). The set of data is too small to determine unequivocally a cause of such phenomenon. Reversal of the current in 12 hours (Fig. 7) is significant. A diurnal component of tidal amplitudes is large off the coast of the South Shetland Islands (Vorobiev 1972) and fluctuations of sea level may cause such phenomena. However, it cannot be ruled out although it seems less probable, that movement of water masses was caused by wind. Detailed explanation of mechanism of the observed phenomenon would be possible only after long-term twenty four hour observations at least at two stations (nos. 11, 14 — see: Fig. 1), correlated with tide studies and measurements of wind directions and velocity. Taking into account the observed variability, the time interval between successive series of measurements taken at a station should not exceed four hours.

Acknowledgements. — The authors would like to acknowledge S. Misiaszek and M. Rzepecki, who contributed in the collection of data. We also acknowledge Professor S. Rakusa-Suszczewski for his advice and critical remarks.

References

Bojanowski R. 1984. Hydrochemical observations at an anchored station in Ezcurra Inlet. — Oceanologia, 15: 21—62.

Catewicz Z. 1984. Variability of the water flow in Ezcurra Inlet. — Oceanologia, 15: 75—96.

Kopczyńska E. E. 1980. Small-scale vertical distribution of phytoplankton in Ezcurra Inlet. — Pol. Polar Res., 1 (4): 77—96.

Pęcherzewski K. 1980. Distribution and quantity of suspended matter in Admiralty Bay. — Pol. Polar Res., 1 (1): 75—83.

Pond S. and Pickard G. L. 1978. Introductory to dynamic oceanography. — Pergamon Press, Oxford, 55—79.

Pruszak Z. 1980. Currents circulation in the waters of Admiralty Bay. — Pol. Polar Res., 1 (1): 55—74.

Rakusa-Suszczewski S. 1980. Environmental conditions and the functioning of Admiralty Bay as part of the near shore Antarctic ecosystem. — Pol. Polar Res., 1 (1): 11—27.

Samp R. 1982. Selected environmental factors in the waters of Admiralty Bay. — Pol. Polar Res., 1 (4): 53—66.

Szafrański Z. and Lipski M. 1982. Characteristics of water temperature and salinity at Admiralty Bay during the austral summer 1978/79. — Pol. Polar Res., 3: 7—24.

Vorobiev V. N. 1972. Niekotoryje certy gidrologicheskogo rezima v rajonie stancji Bellingshausen. — Trudy Antarkt. Sov. Exped., 55: 182—187.

Wright F. F. 1971. Fiord circulation and sedimentation Southern Alaska. — Proc. First Inter. Confer. Port and Ocean Engeneer Arctic Condit., 1: 279—284.

Wróbel F. 1977. Operacje rozładunkowe w rejonie stacji Arctowskiego. — Nauka Polska, 25: 127—130.

Received July 10, 1987
Revised and accepted October 14, 1987

Streszczenie

Podczas lata antarktycznego w 1982 r. wykonano przy użyciu automatycznej sondy Martek MK-IV sieć pomiarów temperatury, zasolenia i zawartości rozpuszczonego tlenu na 24 stacjach w Zatoce Admiralicji, Wyspa Króla Jerzego, Antarktyka Zachodnia (fig. 1). W celu oceny zmienności rejestrowanych parametrów przeprowadzono jednodobowe obserwacje na 4 stacjach wzdłuż przekroju Martel Inlet — Ezcurra Inlet (fig. 1). Uzyskane wyniki wykazały występowanie w zatoce dwu mas wodnych ułożonych horyzontalnie jedna nad drugą (fig. 2—4). Granica pomiędzy nimi przebiega zwykle na głębokościach 15—35 m. Główna masa wód napływa

z Cieśniny Bransfielda i wypełnia zatokę od dna do okolic powierzchni. Wody te są jednorodne i nie obserwuje się wewnątrz nich wyraźnych zmian sezonowych. Górna, cienka warstwa wód jest bardzo zróżnicowana i obserwuje się w niej często lokalne minima zasolenia, oraz lokalne maksima temperatury i zawartości rozpuszczonego tlenu. Te ostatnie (fig. 6) wydają się mieć związek z rozmieszczeniem fitoplanktonu. W porównaniu z główną masą wodną cienka, górna warstwa jest chłodniejsza, mniej zasolona i charakteryzuje ją podwyższona zawartość rozpuszczonego tlenu. Wytwarza się ona wskutek interakcji głównej masy wodnej z wodą wytapianą z lodu i paku. Prawdopodobnie, wskutek występujących latem warunków klimatycznych jest ona produkowana wzdłuż całego archipelagu. Prądy powierzchniowe transportują ją w głąb zatoki, gdzie ulega ona dalszemu rozcieńczeniu i ochłodzeniu (fig. 3—5). Występujące w zatoce prądy powodują mieszanie się obu warstw i są przyczyną występowania lokalnych, krótkotrwałych, znacznych różnic w wartościach obserwowanych na danej stacji parametrów (fig. 7).