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# Antarctic oceanobiological expeditions organized by the Polish Academy of Sciences

ABSTRACT: The paper provides information on oceanobiological expeditions to the Antarctic organized by Polish Academy of Sciences. The scope of research of five expeditions is described and main achievements of Polish Antarctic studies are summarized.

Key words: Antarctica, oceanobiology, Poland.

## Introduction

Twenty years have passed in 1995 since the beginning of the Ist Polish Antarctic Marine Research Expedition. In 1997 we also celebrated a centennial of the departure of the famous *Belgica* expedition to the Antarctica and the participation in this cruise of first two Poles – Henryk Arctowski and Antoni Bolesław Dobrowolski.

Today, more than 20 years of continuous Polish marine biological studies in the Antarctic allow us to summarize the main lines of research undertaken by several successive Polish marine expeditions to the Southern Ocean (Fig. 1).

## First reconaissances

Polish biological studies in the Antarctic commenced in the late sixties. Groups of Polish biologists participated, as scientifically independent parties, in the 14th, 17th, and 19th Soviet Antarctic Expeditions (1968/70, 1971/72,

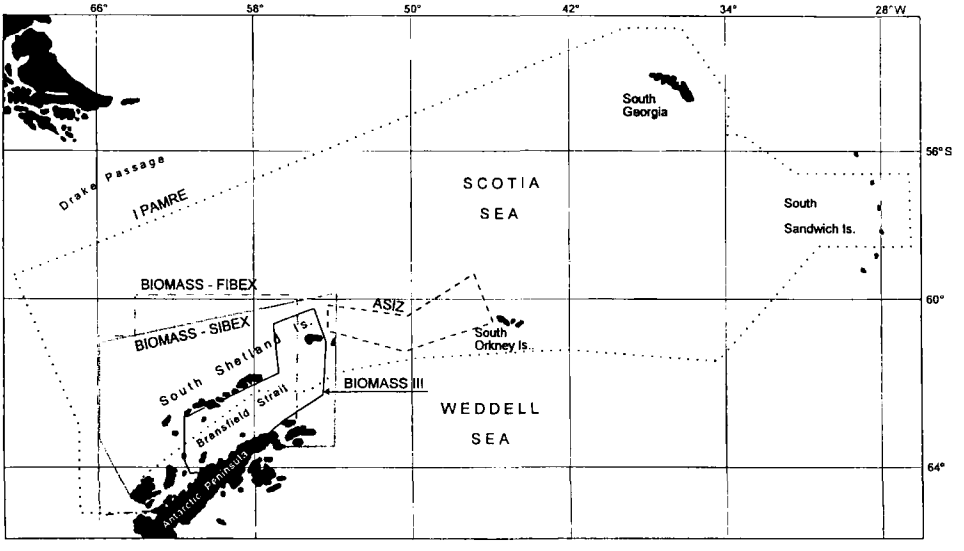


Fig. 1. Study area of Polish oceanobiological expeditions to West Antarctic organized by Polish Academy of Sciences.

1973/74). These small groups of scientists (2–4 persons), all led by the senior author, were officially named the Ist, IInd and IIIrd Polish Antarctic Biological Expeditions (PABE). All worked at the Soviet *Molodezhnaya* Station situated in the Thala Hills oasis (Enderby Land, East Antarctica). There, Polish scientists studied flora and fauna of freshwater bodies (Opaliński 1972a,b), the sub-fast-ice communities at the shores of the Southern Ocean (Rakusa-Suszczewski 1972), as well as the biology, ecology and physiology of some marine crustaceans and fishes (Jakubowski *et al.* 1969; Jakubowski 1970, 1971, 1975, 1982; Jakubowski and Byczkowska-Smyk 1970; Klekowski *et al.* 1973; Rakusa-Suszczewski and Klekowski 1973; Jakubowski and Rembiszewski 1974; Jażdżewski 1974; Opaliński 1974).

## Ist PAMRE Expedition (1975/76)

These fruitful scientific beginnings together with the increasing political and economical interest of our country in the Southern Ocean led to an important decision in 1975. The Polish Academy of Sciences, in co-operation with the Sea Fisheries Institute and Fishing Company *Odra*, organized the Ist Polish Antarctic Marine Research Expedition (PAMRE) to the western Antarctic (Scotia Sea, Drake Passage and Bransfield Strait). Two ships were sent, namely r/v *Profesor Siedlecki* (Fig. 2) and m/t *Tazar*. The leadership of this expedition was entrusted

to D. Dutkiewicz and S. Rakusa-Suszczewski; the ship's master was M. Babiak. The main goals of the expedition were:

a) Krill catches to provide material to be used by various institutions in studies of krill utilization as a new foodstuff and fodder;

b) Studies on krill populations structure, their dynamics, and distribution in the western Antarctic;

c) Studies of basic environmental factors in the region of krill agglomerations to analyze the possible correlations between these parameters and the occurrence of krill swarms;

d) Hydroacoustic characterization of krill agglomerations and their vertical migrations.

Scientists were organized in several teams: (1) An oceanographic team studied physical and chemical parameters at 72 stations; (2) A hydroacoustic team, in day and night watches took soundings along nearly 8800 nautical miles; (3) A biological team analyzed over 150 krill populations (length, age, sex structure and fecundity) from commercial krill catches; (4) A bioenergetics and biochemical team measured the metabolism and respiration of different krill stages and studied concentrations of heavy metals and insecticides in krill, fishes, and birds; (5) An ichthyological team studied demersal fishes and fish obtained as by-catch in krill commercial hauls (body length, weight; population structure); (6) A computer team, preparing the data bank DAKRYL, tried to map out possible correlations between the results obtained by all teams.

The expedition lasted from December 22, 1975 till July 1, 1976. The results of this largest-ever Polish marine research enterprise were soon published as a separate volume of *Polskie Archiwum Hydrobiologii (Polish Archives of Hydrobiology)* in 1978 (Vol. 25, No. 3) permanently introducing our country into the then-limited family of states seriously studying the Antarctic. This first marine expedition thus gave a scientific base for further commercial fishery enterprises.

## BIOMASS Programme

An international BIOMASS (Biological Investigations of Marine Antarctic Systems and Stocks) programme started in 1976. It arose from the growing interest of many countries in the living resources of the Southern Ocean – mainly krill, fishes, and squids. The main objectives of the BIOMASS programme were "To gain a deeper understanding of the structure and functioning of the Antarctic marine ecosystems as a basis for the management of actual and potential living resources" (Anon. 1977).

This BIOMASS programme was planned for 10 years and included oceanographic surveys, studies on krill and fish populations structure and fishery statistics, laboratory experiments on krill, bird and seal censuses at sea and in

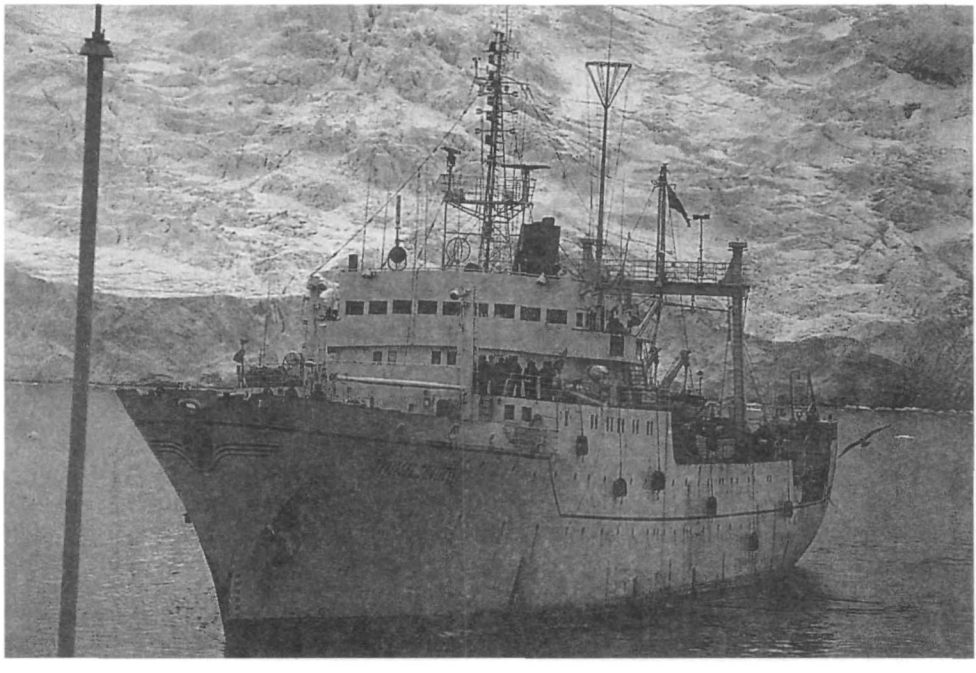

Fig. 2. r/v *Profesor Siedlecki* in the Antarctica.
*Photo by K. Jażdżewski.*

rookeries, etc. It is easy to see that the program and results of the Ist PAMRE were of major importance as a sound scientific base for future expedition enterprises, fitting exceptionally well into the planned BIOMASS objectives.

In the framework of the BIOMASS programme Polish scientists again studied the area of the southern part of the Drake Passage and Bransfield Strait, *i.e.* the area around the South Shetland Islands. This enabled to relate BIOMASS results with those obtained during the Ist PAMRE, operating formerly in the same area, as well as with the studies carried on at the Polish Antarctic Station *H. Arctowski* situated at Admiralty Bay, King George Island (South Shetland Islands). All Polish BIOMASS expeditions were organized by the Institute of Ecology of Polish Academy of Sciences (IE PAS) and were conducted on board the r/v *Profesor Siedlecki*, repeatedly chartered by the Sea Fisheries Institute in Gdynia, a major cooperating institution.

## FIBEX Expedition (1981)

The first part of the BIOMASS programme was the so-called FIBEX (First International BIOMASS Experiment) – a joint, complex program of oceanographi-

cal studies of the Southern Ocean carried out by 13 vessels from 11 states. The Polish FIBEX expedition started study in the *A* area on 14th February and finished on 21st March, 1981. S. Rakusa-Suszczewski was the head of the expedition with P. Bykowski acting as his deputy chief scientist. The ship's master was again M. Babiak. During the first phase of the expedition research was conducted along 11 transects and on 67 oceanographic and krill catching stations. In the second phase of the expedition, in a small sector of Bransfield Strait south of Admiralty Bay, the research was carried out on 43 stations. Thirty scientists were divided into several working teams: (1) A hydroacoustic team estimated krill biomass along transects; (2) An oceanographic team measured physical and chemical parameters, including the total energy of solar radiation coming to the sea surface and underwater downwelling irradiance at standard depths as well as meteorological phenomena; (3) A microbiological – biochemical team determined the amount of chlorophyll and phaeophytin, dissolved free- and combined amino-acids, dissolved mono- and polysaccharides and urea, and vertical and horizontal distribution of saprophytic bacteria; (4) A planktonic team determined the settling volume and dry weight of total plankton, qualitative and quantitative composition of net phytoplankton and phytoplankton in quantitative Nansen bottle samples, and species composition of zooplankton. In addition, biological analyses of krill were performed including body length, sex, maturity stage, as well as the degree of gut filling and gut contents composition; (5) An ichthyological team studied the distribution and abundance of juvenile fish within swarms; (6) An ornithological team made observations of avifauna along transects.

The major results of the Polish FIBEX Expedition were published in *Polish Polar Research* (1982, Vol. 3, No. 3–4) and in *Atlas of Polish oceanographic observations in Antarctic waters* (1985, BIOMASS Spec. Issue, Scott Polar Res. Inst., Cambridge).

## SIBEX Expedition (1983/84)

Polish expedition in the second stage of BIOMASS programme – SIBEX (Second International BIOMASS Experiment) was organized in the austral summer 1983/84 again on board the r/v *Profesor Siedlecki*. The study area included Bransfield Strait east of Anvers Island as far as 54W and Drake Passage along the northern coasts of the South Shetland Islands. The research was carried out at 218 stations from December 10, 1983 to January 8, 1984. S. Rakusa-Suszczewski and P. Bykowski were again the scientific leaders of the expedition, whereas the ship's master this time was R. Ludwig. The research staff was divided into the following groups: (1) A hydroacoustic team made continuous soundings enabling to estimate krill swarms in the epipelagial; (2) A meteorological team made observations at synoptic hours and at oceanographical sta-

tions; (3) A hydrological team studied water quality by TS analysis and determination of the contents of chlorophyll a, DOC, POC, dissolved free- and combined amino-acids; (4) A microbiological team determined the amount of bacteria in general and the amount of saprophytic bacteria in particular; (5) A planktonic team analysed the settling volume and dry weight of suspensed dead and living particulate matter, the quantity and quality of net and bottle phytoplankton, as well as the species composition, age, and sex structure of mesoplankton; (6) A krill biology team identified body length, sex, maturity stage and gut filling of about 100 krill individuals from each catch; (7) An ichthyological team analysed adult and post-larval stages of fishes from pelagic trawls; (8) An ornithological team counted birds every half an hour during a day; (9) A cartographic team prepared different scale maps of the research area (a lot of soundings were done for a new version of a bathymetric chart); (10) A computer team computed all the results obtained.

Most of the results of Polish SIBEX Expedition have been published in *Polish Polar Research* (1985, Vol. 6, No. 1–2).

## BIOMASS III Expedition (1986/87)

All the above-reported Polish Antarctic marine studies until this time were conducted during austral summers or in autumn. To complete their observations, the next BIOMASS III Expedition began its observations in early austral spring 1986 and continued them in summer 1987. The cruise was held on r/v *Profesor Siedlecki* and the area of studies were wide vicinitities of the South Shetland Islands between 60 and 64°S, and 54 and 61°W. The expedition's leader was again S. Rakusa-Suszczewski while the ship's master was Z. Ossowski.

The studies covered confluence zones of water masses of different origin and samples were collected in the water column down to 2000 m. In this expedition Spanish and American teams participated. Polish scientific staff was organized, as formerly, in several cooperating groups studying: (1) hydrology and hydrochemistry of the studied region; (2) microorganisms in sea water; (3) phyto- and zooplankton; (4) the structure of krill populations; (5) biomass and migrations of krill swarms by hydroacoustic methods; (6) pelagic and demersal fishes, (7) parasites of fishes, birds, and seals; (8) chlorinated hydrocarbons content in marine organisms.

Due to the difficult ice conditions of early austral spring (October / November) and the comparatively long length of the expedition this was the hardest cruise carried out of all to date, both for the vessel and the staff. Scientific goals were achieved, among others, thanks to the close cooperation with teams of the Xth and XIth expeditions of Polish Academy of Sciences working at the *Arctowski* Station. Polish m/t *Koral* helped the Spanish team to collect additional

hydrological data in Bransfield Strait. At the end of the expedition ichthyological and parasitological materials were collected in the South Georgia area.

The results obtained during this cruise were published primarily in *Polish Polar Research* (1988, Vol. 9, No. 2–3).

## ASIZ Expedition (1988/89)

The purpose of the most recent Polish marine expedition to the Southern Ocean, organized during the austral summer of 1988/89 (December – January), was to study the Antarctic Sea Ice Zone (ASIZ) in the northern region of the Weddell Sea between Elephant Island and the South Orkney Islands. The expedition, on board r/v *Profesor Siedlecki* (master J. Sokołowski), led by S. Rakusa-Suszczewski, was organized in teams studying: (1) hydrology and hydrochemistry; (2) microorganisms in water and in pack-ice; (3) phyto- and zooplankton; (4) fishes, mainly ichthyoplankton; (5) krill swarms distribution and migrations.

The main part of the results of this expedition was presented again in a separate issue of *Polish Polar Research* (1991, Vol. 12, No. 4).

## A review of scientific results

Physical and chemical properties of waters in the studied sector of the Antarctic have been described in papers by Chłapowski and Grelowski (1978), Wensierski and Woźniak (1978), Pęcherzewski (1978), Rakusa-Suszczewski (1978b, 1988b), Stramski and Montwiłł (1982), Mężykowski (1982), Grełowski and Tokarczyk (1985), Zdanowski (1985), Grelowski *et al.* (1986), Tokarczyk (1987), Grelowski and Wojewódzki (1988) and Tokarczyk *et al.* (1991). Owing to these studies a much better understanding of the quality and movements of water masses in the western Antarctic was gained. A part of this analytic effort was summarized in the papers by Stein and Rakusa-Suszczewski (1983, 1984).

An important cartographic result to arise from the BIOMASS expeditions were the new bathymetric charts of Bransfield Strait (Szeliga 1985, 1991).

Living organisms were studied in all trophic levels. Primary production was estimated by studies of chlorophyll content (Lipski 1982, 1985, 1991; Lipski and Zieliński 1988), whereas the quality and quantity of phytoplankton was determined by Kopczyńska and Ligowski (1982, 1985), Kopczyńska (1988, 1991, 1992), Ligowski (1988), and Ligowski and Kopczyńska (1991). Sea ice algae were also studied, yielding new data on the quality and abundance of diatoms in this peculiar habitat and stressing the importance of pack-ice as a source of inoculation with diatoms of pelagic waters following spring melting (Ligowski *et al.* 1988, 1992; Ligowski 1991).

Zooplankton was investigated during successive expeditions by numerous authors. Complete zooplankton studies were presented by Jażdżewski *et al.* (1982, 1985), Witek *et al.* (1985), Kittel *et al.* (1988) and Siciński *et al.* (1991).

The distribution and quantity, and in some cases also the biology and physiology of particular planktonic groups, were thoroughly studied by various specialists: Tintinnina by Wasik and Mikołajczyk (1990), Polychaeta by Siciński (1988), Copepoda by Żmijewska (1985, 1987, 1988), Amphipoda by Opalinski and Jażdżewski (1978), and Jażdżewski and Presler (1988), Euphausiacea by Kittel and Stępnik (1983) and Kittel *et al.* (1985), and Chaetognatha by Bielecka and Żmijewska (1993). All these papers clearly demonstrated that the composition and abundance of pelagic communities are excellent indicators of water masses of different origin and various oceanic layers.

Special attention was always paid to krill (*Euphausia superba*), a crustacean recognized as a key organism of the Antarctic ecosystem. Polish research on krill encompassed studies of its morphology (Dzik and Jażdżewski 1978, Rakusa-Suszczewski 1994), physiology, biochemistry, behaviour and food composition (Czeczuga and Kłyszejko 1978; Rakusa-Suszczewski and Opaliński 1978; Ligowski 1982; Rakusa-Suszczewski 1982b, 1988c; Bykowski and Kowalczuk 1986; Neugebauer *et al.* 1986), population structure (Jażdżewski *et al.* 1978, Wolnomiejski *et al.* 1982, Czykieta *et al.* 1986, Kittel and Rakusa-Suszczewski 1988) and larval stages distribution (Kittel and Jażdżewski 1982, 1985; Witek and Kittel 1985; Kittel 1988).

An acoustic survey of krill aggregations was carried out in all expeditions. The distribution and biomass of krill concentrations was estimated in vast areas of West Antarctic, giving a sound basis both for future commercial krill exploitation and for human planning of the proper protection measures to be undertaken. Papers presenting spatial distribution of krill swarms and their vertical, diurnal and seasonal migrations were published by Kalinowski (1978, 1982, 1988a, b), Kalinowski *et al.* (1985), Klusek and Godlewska (1988) Godlewska and Klusek (1987, 1988, 1991a, b), Godlewska *et al.* (1991) and Godlewska (1993).

Among the consumers of the higher level more thorough studies were devoted to fishes. Both pelagic fishes collected as by-catch in krill trawlings and demersal fishes caught with bottom trawls were investigated (Rembiszewski *et al.* 1978; Linkowski and Rembiszewski 1978a; Ślósarczyk and Rembiszewski 1982; Skóra and Sosiński 1983; Ślósarczyk and Cielniaszek 1985; Ślósarczyk 1986; Skóra 1988a, b, 1991; Sosiński and Paciorkowski 1993). In some expeditions attention was also paid to birds (Linkowski and Rembiszewski 1978b, Starck and Wyrzykowski 1982, Starck 1985).

An ecological group of destruents – bacteria – was also investigated (Zdanowski 1982, 1985, 1988; Zdanowski and Donachie 1993).

Parasitological studies of Zdzitowiecki (1978, 1979, 1981, 1983, 1986, 1989a–c, 1990a, b–d, 1991b, 1992, 1993), Wojciechowska (1990, 1991a, b,

1993a, b) and Zdzitowiecki and Cielecka (1996) are an important contribution of Polish biologists to the knowledge of the structure and functioning of the Antarctic ecosystem. Many species new to science have been described and hitherto unknown hosts of parasites were identified.

The studies on the contamination of Antarctic organisms at various trophic levels by chlorinated hydrocarbons (CHs) were published by Łukowski (1978a, b), and Łukowski and Ligowski (1987, 1988). It was found that along with the direct atmosphere transport the release of CHs from glaciers, sea ice and bottom deposits is an additional source of important input of chloroorganic biocides into Antarctic waters and subsequently – through the diatoms – to higher trophic levels. Diatoms appeared to be very good indicators of this process.

## Syntheses and monographs

Attempts at syntheses of the results of these expeditions were presented by Rakusa-Suszczewski (1983, 1988d), Rakusa-Suszczewski and Godlewska (1984), Godlewska and Rakusa-Suszczewski (1988), and Godlewska (1989). Polish biologists participating in the above mentioned marine expeditions have also published several monographs devoted to various Antarctic biological problems: the structure of krill swarms, their distribution and migration (Kalinowski and Witek 1985, Godlewska 1995); biotechnological processing of krill (Bykowski 1986), Antarctic acanthocephalans and digeneans (Zdzitowiecki 1986, 1991a, 1997); krill metabolism (Opaliński 1991); Antarctic diatoms (Ligowski 1993); Antarctic marine bacteria (Zdanowski 1995), and zooplankton of the Southern Ocean (Kittel 1996).

## Fishery expeditions

This survey should be supplemented with the results of several fishery expeditions to the Southern Ocean organized by Sea Fisheries Institute and different fishing companies. The scientific efforts of these expeditions focused upon fishery techniques, commercial fish population structure and krill and fish products' manufacturing. All this important activity is summarized in the paper by Chojnacki (1998). The reader is also referred to papers by Bykowski (1986), Sosiński and Skóra (1988), Turkiewicz (1995), and Kulesz and Kompowski (1998).

## Summary of expeditions

Briefly summarizing the scientific accomplishments of all five Polish marine Antarctic expeditions held between 1975 and 1989, one can note that all cruises

were conducted using the same research vessel *Profesor Siedlecki*; they were scientifically supervised by the same leader and many experienced scientists repeatedly took part in successive expeditions. All expeditions operated approximately in the same area of the West Antarctic, namely the Scotia Sea, northern part of Weddell Sea, in the Bransfield Strait and southern Drake Passage. Except for the Ist PAMRE, all further expeditions received strong logistic support from the Polish Antarctic Station *H. Arctowski*, founded in 1977 on King George Island (South Shetlands), *i.e.* in the middle of the researched area. Reports on all five cruises of r/v *Profesor Siedlecki* in the Southern Ocean area have been published by Ludwig and Babiak (1978), Rakusa-Suszczewski (1978a, 1982a, 1988a, 1991) and Rakusa-Suszczewski and Lipski (1985).

The core studies of all Polish Antarctic marine expeditions have remained basically the same – aiming at a closer understanding how the structure and functioning of Antarctic biota are conditioned by the hydrology of this most dynamic part of the Southern Ocean.

The scientific interest of our oceanobiologists was concentrated in the uppermost productive layer of Antarctic waters to depths of 100 m. We attempted at recognizing zones of steep gradients of particular factors characteristic of regions of high dynamics, in order to find those environmental conditions which would indicate the concentrations of planktonic organisms and fishes. The relation between the stability of water column and chlorophyll distribution was demonstrated. Local conditions such as strong catabatic winds or tides in the coastal zone can disturb water column stability, inducing a decrease in primary production. Our studies allowed to create a picture of the neritic and oceanic waters with the variability range of parameters studied, to determine water dynamics, directions of geostrophic currents and the position of convergence and divergence zones.

Oceanobiological studies repeated during five expeditions have demonstrated seasonal, sometimes rather irregular changes on macro-scale of the whole West Antarctic area studied. Hydrological changes are reflected by fluctuations in the primary production and zooplankton biomass, especially of krill and salps. It appears that the maxima of krill biomass in the Scotia Sea and in the Bransfield Strait have occurred after severe winters.

The last marine expedition of r/v *Profesor Siedlecki* (ASIZ Expedition), working in the open ocean along the pack-ice line from the Elephant Island to South Orkney Islands, reflected the new interest of European oceanobiologists engaged in the program EPOS (European *Polarstern* Studies). Our results, which determined the position of polar front Weddell Sea/Scotia Sea, were complementary to the EPOS studies. We were able to recognize two types of water masses: warm deep waters of the Drake Passage and cold surface waters coming from the Bransfield Strait. Eastwards strongly mixed waters of Weddell/Scotia Confluence occurred; in the South Orkneys area they were diluted at the surface

because of the pack-ice melting. This region of strong stratification appeared to be very productive. The pack-ice clearly influenced the distribution of bacteria, phytoplankton, zooplankton and krill. Dynamics of the sea surface covered with ice is responsible for the biodiversity of the pelagic ecosystem, which can change very quickly. Local hydrological and biological phenomena are of importance for the whole Antarctic ecosystem, but cannot be simply extrapolated to the larger parts of the ocean at the same time. Horizontal and temporal variability of biological processes is very high.

The differences between hydrological and biological conditions in the coastal, neritic and oceanic zones, well-documented by Polish studies among others, constituted a basis for the creation of a new, international programme CSEASIZ (Coastal and Shelf Ecology of Antarctic Sea Ice Zone), which will be realized till 2004.

We would like to close our review of the Polish biological studies carried out in the Southern Ocean during the five scientific cruises on board r/v *Profesor Siedlecki* with a warm word of praise given to Polish oceanobiologists by Prof. Dr. S. El Sayed, a convenor of a Group of Specialists in the Southern Ocean and their Living Resources in his preface to the *Atlas of the Polish Oceanographic Observations in Antarctic Waters*, published by Scott Polar Research Institute in Cambridge (1985) :

"I would like to record my sincere congratulations and admiration to our Polish colleagues for their great efforts in producing the *Atlas* and for the valuable contribution they have made and are continuing to make in our knowledge of the seas surrounding the Antarctic Peninsula".

Although these kind words concerned only a part of our national scientific achievements in the field of Antarctic ecosystem studies, we think that the results of other expeditions of similar scope, results which have been quickly published and are well cited, deserve a similar appraisal. We hope that this present summary of Polish oceanobiological activity in the Southern Ocean well justifies all the organizational and financial efforts Poland has offered to support knowledge of such a remote region of the Earth.

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