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Biological and ecological studies carried out at the Polish Antarctic Station *Henryk Arctowski*, 1977–1997

ABSTRACT: The authors describe the scope of Polish studies in the field of biology and ecology carried on during 20 years of activity of Polish Antarctic Station. Principal results are briefly summarized and ample literature is presented.

Key words: Antarctica, *Arctowski* Station, biological studies.

Introduction

The scientific successs of the consecutive Polish Antarctic Biological Expeditions (1968/70, 1971/72, 1973/74) as well as of the Ist Polish Antarctic Marine Research Expedition (1975/76) led to the decision of the Polish Governement to built a Polish Station in Western Antarctica[1].

It was built on King George Island (South Shetland Islands) at Point Thomas, Admiralty Bay, during two months of the austral summer 1976/77. The Station was named *Henryk Arctowski* after the scientific leader of the famous *Belgica*

[1] One of principal goals of this decision was Polish membership in the Antarctic Treaty Consultative Parties. In 1958, Poland received from Soviet Union their base *Oasis* situated at Bunger Hills, Eastern Antarctica, opened it in 1959 and renamed after *Antoni Bolesław Dobrowolski*. This station has not been occupied permanently and thus was not fullfilling the prerequisite conditions, even though Poland signed the Antarctic Treaty in 1961.

expedition (1897–99) commanded by Adrien De Gerlache. The Station was opened on 26 February 1977. It is located on a rather vast coastal plain with several freshwater ponds and mossy tundra carpets, bordered from the sea by storm ridges and some cliff rocks (Figs 1 and 2).

The Station consists of one large dwelling house used as a hotel by wintering groups (kitchen, bathroom, WC, dining-rest room, reading room and single-person bed-rooms for 13 people), several laboratory buildings (meteo, biology, geophysics), 2 large storage halls, a power-plant building and some "summer" houses for seasonal groups. A large tank for diesel oil is situated some 800 m to the north of the Station.

The *Henryk Arctowski* Station owns a small cutter *Słoń Morski* (length 9 m), equipped with an echosounder and winch enabling trawling, dredging and using bottom samplers down to the greatest depths of Admiralty Bay (over 500 m), as well as for hauling planktonic nets and using a variety of hydrological equipment (Fig. 3). A former boat used in oceanobiological research at the Station was named *Dziunia* (length 7 m); the boat is now exhibited at the marine museum in Hel (Fig. 4).

Scope of scientific research

From the very beginning, the studies carried on at the *Arctowski* Station were multidisciplinary. They included geophysics, geology, pedology, palaeontology, meteorology, geodesy, hydrology, biology and ecology. The latter three fields of studies, in accordance with the scientific interests of the supervising institutions (formerly the Institute of Ecology of Polish Academy of Sciences, now Department of Antarctic Biology Pol. Acad. Sci.), were hitherto represented by the highest number of researchers. The total number of scientific papers published based on the material collected at *Arctowski* Station in these fields is estimated at some 400.

Biological and ecological research: background studies

The main scientific efforts of Polish biologists and ecologists working at the *Arctowski* base has been directed toward recognition and description of the structure and functioning of the marine ecosystem of Admiralty Bay and land biota of King George Island, mainly of the nearest vicinity of the Station, *i.e.* along the south-western shores of Admiralty Bay.

Admiralty Bay is a trifurcated fjord with maximum depth of over 500 m and a total surface of ca 120 km^2. Its shoreline is some 83 km long; ice-free shores

constitute over 53% of the whole shoreline (Rakusa-Suszczewski 1980, Rakusa-Suszczewski *et al.* 1993a).

The ultimate goal of all biological studies, in accordance with an ecological approach of the leading institutions managing the *Arctowski* Station, is to gain an understanding of the functioning of the Antarctic near-shore ecosystem by the quantitative evaluation of all possible links of the trophic chain. Research has been carried out mostly in unknown regions, where the background for ecological studies needed to be studied first. These basic studies included investigations in the fields of geodesy, geomorphology, climatology, meteorology and hydrology (Rakusa-Suszczewski 1993c–e, Rakusa-Suszczewski *et al.* 1993b, c). Detailed maps were prepared (Furmańczyk and Marsz 1980; Battke 1981, 1990), and morphometry of the shores and basic ecological characteristics of Admiralty Bay region were presented (Marsz 1984, Marsz and Rakusa-Suszczewski 1987, Rakusa-Suszczewski 1995a). Climatic conditions were studied both in macroscale (Styszyńska 1990) as well as in microscale (Moczydłowski 1986, Schroeter *et al.* 1995).

Recognition of physical and chemical properties of the environment of Admiralty Bay, sometimes also of the adjoining Bransfield Strait, constituted a basis for all further ecological studies (Pęcherzewski 1980, Pruszak 1980, Samp 1980, Szafrański and Lipski 1982, Bojanowski 1984, Catewicz and Kowalik 1984, Woźniak *et al.* 1984, Lipski 1987, Tokarczyk 1987, Sarukhanyan and Tokarczyk 1988, Madejski and Rakusa-Suszczewski 1990, Lipski and Rakusa-Suszczewski 1990, Rakusa-Suszczewski 1996). These studies have proved the low stability of the Admiralty Bay waters, the lack of a distinct thermocline, halocline and pycnocline. It was found that the wide contact of Admiralty Bay with Bransfield Strait waters and the system of currents allow Admiralty Bay water to exchange within 2 weeks.

Plankton of Admiralty Bay

Microbiological studies of Admiralty Bay were carried out mainly by Zdanowski (1981, 1988, 1995), Zdanowski and Donachie (1993) and Donachie (1995). A considerable variability in the amount of saprophytic bacteria over longer than seasonal scales was observed. It was also suggested that the reason for this variability could be the varying abundance of krill in the Bay. Special attention was paid to the microorganisms occurring in krill stomachs (Rakusa-Suszczewski and Zdanowski 1989) and to the role of bacteria in the process of krill decomposition and autolysis (Zdanowski 1981, 1988, 1995; Donachie 1995). A large culture collection of ca 500 bacterial strains has been assembled, deriving from various marine habitats, in order to compile nutritional profiles for these strains.

It appears that 93% of primary production takes place in the 25-m thick euphotic layer of Admiralty Bay. Primary production and chrolophyll contents have been studied by Hapter *et al.* (1984), Tokarczyk (1986), Lipski (1987) and Domanov and Lipski (1990). Daily primary production fluctuates in a wide range, depending on the season and the region of Admiralty Bay, being the lowest in inner inlets where water transparency was reduced. In general, the average values of primary production approach those of the open waters around South Shetland Islands. Total annual production in surface waters of the central basin of Admiralty Bay is etimated at 6.6 g C m^{-3}.

The phytoplankton of Admiralty Bay was investigated by Kopczyńska (1980, 1981) and Ligowski (1986, 1993a).The nanoplankton is composed of flagellates (12–15 mm), Prasinophyceae, Cryptophyceae and "monads" (4–6 mm). Maximum numbers were recorded during the austral summer in February; algal concentrations ranged from 35×10^3 to 1600×10^3 cells dm^{-3}. In net phytoplankton diatoms dominated, with such taxa as *Thalassiosira antarctica, Nitzschia cylindrus, Corethron criophilum* and *Thalassiothrix* spp. as main components. Altogether 168 diatom taxa in the phytoplankton were recognized. As was expected, the highest phytoplankton densities occurred in the austral spring and summer, the lowest – during winter (April – October).

Sea-ice algae in Admiralty Bay were studied by Ligowski (1987, 1993a,c). Three different diatom communities were discovered in ice-floes with different characteristic species. In all, as many as 138 diatom taxa were identified in the sea-ice from Admiralty Bay. Earlier assumptions that the physical concentration of algae takes place during sea-ice formation have been confirmed. The diatom cells' density in ice was found to be even 2500 times higher than in the surrounding water.

Ligowski (1985), during his studies of the diet of krill in Admiralty Bay, was able to demonstrate that *Euphausia superba* consumed considerable amounts both of sea-ice algae and of epibenthic/epiphytic diatoms. It was concluded that in the near-shore, neritic conditions krill supplements its primarily planktonic diet with sea-ice- and benthic micro-algae.

In zooplankton some groups were more thoroughly studied. Protozoans of the Tintinnina suborder were investigated by Wasik and Mikołajczyk (1993, 1994), who found 17 tintinnid species in the Admiralty Bay and in adjacent Bransfield Strait waters, with *Cymatocyclis convallaria* and *Codonellopsis balechi* being dominants. Tintinnids occurred only in the uppermost 50 m layer, with maximum density up to 4000 ind. m^{-3}. The ultrastructure of *C. convallaria* was also studied, discovering new interesting morphological data.

The Copepoda of Admiralty Bay have been studied by several Polish authors (Chojnacki and Węgleńska 1984, Żmijewska 1993). Thirty nine species have been recorded, with clear dominance of *Metridia gerlachei*; next in terms of abundance were *Euchaeta antarctica, Calanoides acutus* and *C. propinquus*.

The yearly cycle of zooplankton in Admiralty Bay waters was investigated by Menshenina and Rakusa-Suszczewski (1992).

Special attention in zooplankton studies was paid to Euphausiacea. Five species of this group were recorded in Admiralty Bay: *Euphausia superba, E. frigida, E. triacantha, E. crystallorophias* and *Thysanoessa macrura*. Studies were carried out on the morphology of postlarval stages (Kittel and Presler 1980), and on the diet of some euphausiid species (Kittel and Ligowski 1980, Ligowski 1993b). Krill – *Euphausia superba* – was obviously the most thoroughly studied species. Its population structure was investigated by Jackowska (1980), Kittel (1980), Rakusa-Suszczewski and Stępnik (1982) and Stępnik (1982); the growth and mortality of *E. superba* by McClatchie *et al.* (1991); whereas its commensals and parasites – by Stawiszyńska-Janas and Kittel (1982), Rakusa-Suszczewski and Filcek (1988), Rakusa-Suszczewski and Nemoto (1989) and Stankovič and Rakusa-Suszczewski (1996).

Benthos of Admiralty Bay

In the sediments and on benthic macroalgae of Admiralty Bay, 120 diatom taxa were found (Ligowski 1993b,d). In different depths various diatoms dominated. Attempts to estimate the total microphytobenthos production in the basin studied clearly showed that the role of this primary production is very significant.

Zieliński (1981, 1990) studied the macrophytobenthos of Admiralty Bay. His studies have brought a list of 36 macroalgal taxa, among them 20 species of Rhodophyta, 10 species of Thallophyta, 5 species of Chlorophyta and 1 species of Chrysophyta. The most common taxa were *Monostroma harriotti, Iridaea cordata, Adenocystis utricularis, Ascoseira mirabilis, Desmarestia* spp. and *Himantothallus grandifolius*.

Macroalgae occur in Admiralty Bay down to the depths of 90–100 m. The extension of their meadows was estimated by air photographs analysis (Furmańczyk and Zieliński 1982) at some 30% of Admiralty Bay surface bottom.

Polish studies of zoobenthos of Admiralty Bay are ranked among the most comprehensive investigations of the Antarctic bottom fauna (Knox 1994). Along with qualitative faunistic studies (Jażdżewski 1981, 1993; Arnaud *et al.* 1986; Siciński 1986, 1993; Jażdżewski *et al.* 1991, 1992, 1995; Siciński and Janowska 1992; Presler 1993b; Błażewicz and Jażdżewski 1996, 1997; Presler and Figielska 1998) in which over 400 invertebrate taxa have been recorded, our investigations have brought the quantitative estimation of the abundance and biomass of zoobenthos of Admiralty Bay (Jażdżewski *et al.* 1986, 1991). Polychaeta and Amphipoda appear to be the most diverse animal groups – about 120 species of each group. In terms of abundance Bivalvia and Polychaeta predominate, where-

as in terms of biomass, in shallow waters, bivalve molluscs also predominate, yielding in the deeper sublittoral to Ascidiacea, Echinodermata, and Bryozoa. Maximum densities of zoobenthos observed ranged up to over 36000 ind. m^{-2} and over 2500 g m^{-2}, but estimates drawn from some underwater pictures indicate the presence of higher biomass values per m^2. The average biomass of the benthos increases from ca 250 g m^{-2} in the shallow sublittoral (10–15 m) to over 1000 g m^{-2} at the depths 100–200 m, and then decreases in the deepest parts of the Bay (400–500 m) to about 300 g m^{-2} (Jażdżewski and Siciński 1993).

A significant role in the Antarctic benthic communities is played by necrophagous animals. This ecological group was studied by Presler (1986, 1993a) who recorded 23 scavenging species (among others 5 lysianassoid amphipods and 11 asteroids) in Admiralty Bay and has presented their depth preferences and seasonal changes in the distribution of particular necrophagous taxa.

Autecological study of a littoral gastropod, *Nacella concinna*, was carried out by Filcek (1993).

Fishes of Admiralty Bay

The studies of fishes inhabiting Admiralty Bay commenced with the first wintering (1977/1978) at the *Arctowski* Station. They included faunistic studies (Żukowski 1980) as well as observations on the growth, respiration, and food habits of nototheniid fishes (Linkowski and Żukowski 1980, Linkowski *et al.* 1983, Kulesz 1994). Further ichthyological studies were carried out by Skóra and Neyelov (1992), Skóra (1993, 1995), Kulesz and Zadróżny (1996), and Zadróżny (1996). Thirty-nine fish species belonging to 11 families have been hitherto recorded in Admiralty Bay; one third of them belonged to the family Nototheniidae. The most common species are *Notothenia neglecta*, *N. rossi* and *Gobionotothen gibberifrons*. One fish species is new for science (*Acanthodraco dewitti*). Depth-related changes in ichthyofauna of Admiralty Bay have been described. It was observed that the abundance and biomass of fishes in Admiralty Bay were distinctly lower than those of adjacent Bransfield Strait shelf of King George Island.

Birds and mammals of Admiralty Bay

Birds and mammals breeding at the shores of King George Island, and mainly in the *Arctowski* Station area, have been monitored from the very beginning of the station's activity (1977/1978). Altogether twelve nesting bird species and 16 further species visiting King George Island have been recorded by Polish and American ornithologists working in this area (Jabłoński 1980, Presler 1980,

Trivelpiece *et al.* 1987). The census of 3 species of pygoscelid penguins (*Pygoscelis adeliae, P. antarctica* and *P. papua*) and of other nesting birds was carried out by Jabłoński (1984a, b, 1986, 1987), Sierakowski (1991) and Lesiński (1993). Significant fluctuations of the number of breeding pairs of pygoscelid penguins were recorded over the period 1978–1990. The most serious decline in the number of breeding pairs, nearly 3-fold, was observed in *Pygoscelis adeliae*. Moczydłowski (1989) has investigated the nesting strategy of pygoscelid penguins. Detailed studies on the breeding biology of the Wilson's storm petrel (*Oceanites oceanicus*) were carried out by Wasilewski (1986) and on the Antarctic tern (*Sterna vittata*) by Jabłoński (1995).

Short summary of ornithological observations in the Admiralty Bay area was presented by Myrcha (1993).

Five species of pinnipedian mammals occur in the region of Admiralty Bay; one species of fur seal – *Arctocephalus gazella*, and 4 species of seals – *Mirounga leonina, Leptonychotes weddelli, Lobodon carcinophagus* and *Hydrurga leptonyx*, the latter two species being closely associated with pack ice. Monitoring of seals has been consequently carried out for years (Myrcha and Teliga 1980, Presler 1980, Woyciechowski 1980, Krzemiński 1981, Jabłoński *et al.* 1987, Sierakowski 1991, Lesiński 1993, Rakusa-Suszczewski and Sierakowski 1993). The results of this census indicate also to the significant fluctuations of populations of all the monitored species.

Parasites of vertebrates

Parasites of vertebrate animals of King George Island and Admiralty Bay were thoroughly studied by a number of Polish scientists (Zdzitowiecki 1978, 1979, 1985, 1986a–c, 1987, 1991; Zdzitowiecki and Dróżdż 1980; Cielecka and Zdzitowiecki 1981, 1989; Jarecka 1984; Jarecka and Ostas 1984; Zdzitowiecki and Rokosz 1986; Zdzitowiecki *et al.* 1989; Wojciechowska 1993a–c; Cielecka *et al.* 1995; Zdzitowiecki and Cielecka 1996). Many species new to science have been described and some full life cycles recognized. The contribution of our parasitologists and especially that of K. Zdzitowiecki, to the knowledge of parasites of Antarctic vertebrates, must be recognized as one of major achievements of the Polish scientific activity in the Southern Ocean (see Zdzitowiecki 1991b, 1997).

Soil formation studies

Land biota were also investigated by Polish biologists and ecologists working at the *Arctowski* Station. A pioneer research was carried out on the fate of faeces

of numerous penguins in the rookeries of King George Island. Ecological studies by Tatur and Myrcha (1983, 1984, 1989, 1993), Tatur and Barczuk (1984, 1985), Myrcha *et al.* (1985), Tatur (1987, 1989), Myrcha and Tatur (1991) and Tatur *et al.* (1997) have demonstrated that penguins in the rookery regions deposit as much as 10 kg dry weight of guano per square m during one breeding season. It was calculated that about 5% of the ice-free area of Admiralty Bay is affected by the deposition of guano.

This strong fertilization with nutrients leads to the formation of specific ornithogenic soils. Minerals forming these soils were studied in detail; it appears that the composition of phosphates is strikingly diverse. The monomineral accumulations of phosphates and the sequence of changes in mineral composition of ornithogenic soils is unique on a global scale.

The presence of penguin rookeries substantially modifies the fertility of soils in the maritime Antarctic. In the rookery itself, high nutrient contents prevent the development of vegetation that develops, however, at the peripheries of rookeries and then invades the abandoned rookeries. The succession begins with the development of the coprophagous alga *Prasiola crispa* leading to the compact plant communities with diverse composition of species.

Soil microorganisms were studied by Zabawski and Piasecki (1981), Pietr (1986, 1993), Czekanowska and Zabawski (1988), and Zabawski (1995). It was demonstrated that as a result of bacterial activity fresh guano deposited by penguins undergoes mineralization over a period of 3 weeks. Proteolytic bacteria and ammonifiers dominate, while chitinolytic bacteria are also prominent. Eleven species of penicillian fungi were isolated from soil samples. Fungal contribution to the mineralization of penguin guano appears to be very low. In general, in comparison with regions having different climatic regimes, microbial populations of the soils in the Admiralty Bay region displayed greater qualitative and quantitative differences over small areas.

Botanical studies on land

Botanical research of King George Island has been extensively carried out during nearly all Polish expeditions to the *Arctowski* Station. Freshwater and aerophytic algae and Cyanophyceae were studied by Kawecka and Olech (1993, 1996), Luścińska and Kyć (1993) Massalski *et al.* (1994, 1995) and Kawecka *et al.* (1996). 132 species of Bacillariophyceae, 30 species of other algae (Chlorophyceae, Chrysophyceae, Euglenophyceae), and 26 species of Cyanophyceae were recorded (Kawecka and Olech 1996, Mrozińska *et al.* 1996). Macromycetes were investigated by Gumińska *et al.* (1994); 6 species were found and their distribution was described.

Lichenicolous fungi were studied by Olech and Alstrup (1989, 1995), and Alstrup and Olech (*in press*). 65 taxa were discovered, among them nearly half were new to science. A key for determination of this group of organisms in the Antarctic was prepared.

Diverse and thorough research on lichens (lichenized fungi) of King George Island and adjacent regions of maritime Antarctic was carried out by Olech (1989, 1990, 1991a, b), Olech and Alstrup (1989), and Olech and Sochting (1993). In all, over 200 species of lichens were recorded, among them 10 taxa new to science, 51 new to Antarctica, and 30 new to the Southern Hemisphere. A monograph of the genus *Caloplaca* in the Antarctic was prepared (Sochting and Olech 1995).

The distribution of 10 species of liverworts (Hepaticae) in the region of Admiralty Bay was described in details by Ochyra and Vana (1989).

Ochyra and Bell (1984), Ochyra (1985, 1987, 1990), Ochi and Ochyra (1985), Ochyra and Afonina (1986), Ochyra and Ochi (1986), and Ochyra and Lewis-Smith (1996) have studied mosses (Bryophyta) in the wide surroundings of the *Arctowski* Station. They have found over 50 species of mosses there, among them some taxa new to science.

Polish phytosociological research on King George Island was initiated by Furmańczyk and Ochyra (1982), then followed by Olech (1990), who has described 4 ornithocoprophagous communities in the neighbourhood of penguin rookeries. Olech (1994) investigated also the distribution of lichens in the region of Lions Rump (SSSI No. 34), using a 250 × 250 m grid, preparing a map of vegetation.

Vascular plants and their distribution and growth under different experimental conditions, their flowering and fruiting, were studied by Zarzycki (1993), whereas the peat forming vegetation, peat mounds, and the origin and development of mires in the region of *Arctowski* Station were described by Fabiszewski and Wojtuń (1993).

Land and freshwater invertebrates

Land and freshwater invertebrates were also investigated. Niedbała (1986) found 6 taxa of oribatid mites in the material collected at the *Arctowski* Station, among them one species new to science. Jurasz *et al.* (1983), and Janiec (1991) have studied the occurrence, distribution and life cycle of freshwater anostracan crustacean, *Branchinecta gaini*. Janiec (1993, 1996a) has described in detail freshwater invertebrate communities composed of Nematoda, Tardigrada, Rotatoria and Crustacea occurring in ponds and peat bogs of King George Island. Worth mentioning is the fact that this paper belongs to the class of those rare publications where the same author studied similar biotopes in the Arctic and in

the Antarctic, making the comparisons especially valuable. In another paper by Janiec (1996b) attention was focussed on the process of invasion of different taxa into new deglaciated areas and to the succession of the communities.

Biochemical and physiological studies

Physiological and biochemical studies carried out at the *Arctowski* Station have been diversified. Heavy metal contents in Antarctic lichens was investigated by Olech (1991c); lichens were also used as indicators of air pollution in the area of *Arctowski* Station (Szymczyk *et al.* 1994).

The contamination of various Antarctic organisms by the chlorinated hydrocarbons residues (CHs) was studied by Łukowski (1983a, b), Łukowski *et al.* (1987), Karolewski *et al.* (1987) and Łukowski and Ligowski (1987). CHs accumulate in organisms and are concentrated passing from one trophic level to the next. DDT concentration in krill were, on an average, 0.06 ppm, in pygoscelid penguins on average 0.198 ppm, and in leopard seal 0.250 ppm. Due to the studies of planktonic diatoms coming from various areas it was also found that the ice sheet and glaciers in the Antarctic constitute an additional source of contamination by CHs which have accumulated there in the past. It appeared also that the accumulation of CHs is greatest in the diatoms developing in sea-ice.

CHs contamination of flying birds appeared to be dependent on the type of food consumed and on the habits throughout the year. Contamination was higher in species migrating to the northern hemisphere. The diminishing of the contamination of Adelie penguin (*Pygoscelis adeliae*) by DDT residues in last decades was also observed, reflecting worldwide decrease in the use if this insecticide. Studies of pinnipedian contamination by these agents revealed that the highest levels occur in seals feeding on penguins (leopard seals) and on fish (Weddell seal).

Physiological properties of blood in several birds inhabiting King George Island were investigated by Myrcha and Kostelecka-Myrcha (1980a, b) and Kostelecka-Myrcha and Myrcha (1980, 1989). These authors demonstrated significant differences between particular species. Body calorific values of pygoscelid penguins during their development were studied by Myrcha and Kamiński (1982).

Ample biochemical studies of krill (*E. superba*) from Admiralty Bay were also been carried out at the *Arctowski* Station. Many papers were devoted to the lipid content, its seasonal changes in krill, as well as to the lipids oxidability (Kołakowska 1986, 1991a, b). Proteins of krill, their amino-acid composition and their autoproteolysis were studied by Kołakowski (1986a, b, 1987, 1989, 1993), whereas the technical possibility of using autoproteolysis to obtain pro-

tein precipitate was investigated by Kołakowski *et al.* (1980a,b), and Kołakowski and Lachowicz (1982).

Metabolism of krill was studied under different thermic conditions (Rakusa-Suszczewski 1990). High seasonal variability in respiration rate and biomass was observed; in winter a 40% decrease of metabolism was recorded. Respiration of some amphipods and gastropods inhabiting Admiralty Bay has also been investigated (Rakusa-Suszczewski and Lach 1991, Rakusa-Suszczewski 1992).

Ecosystem functioning

Early attempts to present a general pattern of functioning of the ecosystem of Admiralty Bay and its shores were made by Rakusa-Suszczewski (1980a, b, 1987). 15 years after the foundation of the *Arctowski* Station our knowledge has substantially increased due to all the afore-mentioned studies and also many others; it was therefore possible to produce a monograph entitled *The Maritime Antarctic Coastal Ecosystem of Admiralty Bay* (Rakusa-Suszczewski 1993a), summarizing most of the hitherto obtained Polish biological and ecological studies carried out at the *Arctowski* Station. In the introductory and closing articles short quantitative evaluations of Admiralty Bay's functioning as a semi-closed hydrological unit and a very good example of the Antarctic near-shore ecosystem were presented (Rakusa-Suszczewski 1993b, f). This same author has estimated the flow of matter in the Admiralty Bay area (Rakusa-Suszczewski 1995b).

Life in small areas of ice-free Antarctic shores is closely connected with the productivity of the ocean and with the transport of organic matter and nutrients from sea to land. Primary production in Admiralty Bay in austral summer is estimated at over 2300 tons of phytoplankton net weight. The standing crop of benthic microalgae has been calculated at some 13 tons of chlorophyll, whereas that of macroalgae – at about 300 tons. Secondary production of zooplankton, according to the well-known principles, can be estimated at about 230 tons. The biomass of all three pygoscelid penguins in the breeding period was calculated to be about 250 tons. Their daily consumption of krill was estimated at 37 tons. It is therefore evident that Admiralty Bay does not suffice as a foraging ground and penguins have to penetrate much more distant areas.

The competition for food between birds and mammals is probably not very high, since their abundance peaks fall in different months. Main consumers of krill and fishes are sea-elephants and fur seals; the amount of food taken by these two pinnipedians in the region of Admiralty Bay was calculated as 1400 tons. Crab-eater seals alone consume some 630 tons of krill.

Birds and mammals bring organic matter in form of faeces, egg shells, feathers, mollusc shells and hairs on to the land. It was estimated that in the region of rookeries 1.8 kg of organic matter per square m is transported. Ornithogenic soils of abandoned rookeries are then occupied by land vegetation. Freshwater bodies enriched by nutrients are also richer in micro- and meio-organisms.

Impact of human activity on Antarctic ecosystem

One should remember that the land ecosystems in the Antarctic are rather fragile and susceptible to anthropogenic impact. Since the founding of the *Arctowski* Station some 15000 tons of materials, fuel and food were brought on land, whereas only 1500 tons were taken back. Fuel consumption at the *Arctowski* Station fluctuated around 200 t yearly, whereas daily food consumption was about 5 kg, and water consumption about 120 l per person. The functioning of the station and its logistic needs can be better imagined keeping in mind that from the very beginnings till now some 250 persons have wintered at the *Arctowski* Station, and some 600 persons stayed there during austral summer (usually 2–3 months). Several thousand tourists have visited the station and their number is increasing far too quickly (Donachie 1993). Major problems of the anthropogenic impact, mainly upon land biota of King George Island, were signalized by Krzyszowska (1990), Olech (1991c, 1994, 1996a, b), Rakusa-Suszczewski and Krzyszowska (1991) and Rakusa-Suszczewski (1993a, b).

Protection and monitoring of Antarctic environment

The Polish initiative has led to the creation and acceptance by SCAR of the Site of Special Scientific Interest (SSSI) No. 8. This is an area in the vicinity of *Arctowski* Station, on the western shores of Admiralty Bay. In 1990 a successive, scientifically well-substantiated initiative was presented to SCAR, namely the foundation of another SSSI on King George Island (No. 34), situated on western shores of King George Bay; an area remote from human activity and therefore very useful in comparative studies.

In this region of the South Shetland Islands commerial fishing of krill and fish are carried out. The presence of fishery fleets and exploitation of the living resources of the region create serious dangers for the shelf and near shore ecosystem. Polish monitoring of penguins and pinnipedian mammals are in response to SCAR and CCAMLR recommendations. Most of the biological studies carried out at the *Arctowski* Station are complementary to the research conducted during several multinational marine expeditions in the BIOMASS

programme, a fact which has gained high recognition in the international scientific community. Land and inland freshwater studies conducted on King George Island by Polish biologists fit well to the international BIOTAS programme (Biological Investigations of Terrestrial Antarctic Systems).

Final remarks

At present Polish biological studies in the Antarctic are restricted to the near-shore zone where Poland participates in the international scientific program CZ-ASIZ (Coastal Zone – Ecology of Antarctic Sea Ice Zone). In this program the *Arctowski* Station is recognized as a core station.

The wide scope of Polish biological and ecological studies carried out so far over twenty years at the *Arctowski* Station has aided in the recognition and estimation of the natural variability of the maritime Antarctic geo-ecosystem, the understanding of causes of its variability, and the influence of physical parameters and biological responses at the levels of species, populations, or communities.

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