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Human impact upon the environment in the vicinity of *Arctowski* Station, King George Island, Antarctica

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Abstract: During thirty three expeditions to the Polish *Arctowski* Antarctic Station significant influences of human activity upon the environment have been recorded. Introductions of alien species, shifts of bird and seal breeding areas and decreases in both bird and seal populations, are the most obvious effects of human pressure. Though numbers of visits by tourists have increased during this period, impacts from expeditioners appear to be the main cause of changes. In particular, increasing numbers and mobility of summer groups at the station are the likely most influential factors.

Key words: Antarctica, King George Island, human impact.

Introduction

In the scale of historic time Antarctica has only very recently been receiving visits by humans, and these in relatively small numbers. With a considerable expansion of scientific expeditions and their supporting logistics, as well as a remarkable increase of tourism and non-governmental activities, environmental conservation of Antarctica has become an urgent issue (Campbell *et al.* 1994). Increasing numbers of summer tourists visit the continent, particularly Antarctic Peninsula and South Shetland Islands, but governmental personnel, who remain there throughout the year, have opportunities to create considerably greater impacts on terrestrial ecosystems (Riffenburgh 1998).

After the dissolution of the Soviet Union in 1991 a large number of ice-strengthened vessels and icebreakers became available for charter. This led to a rapid increase in the number of tourist visits conducting adventure ecotravels to the Antarctic (Curry *et al.* 2005). Tourism in Antarctica started during the late 1950s: ship-based tourist visits became a regular occurrence from the mid-1960s (Stonehouse 1994).

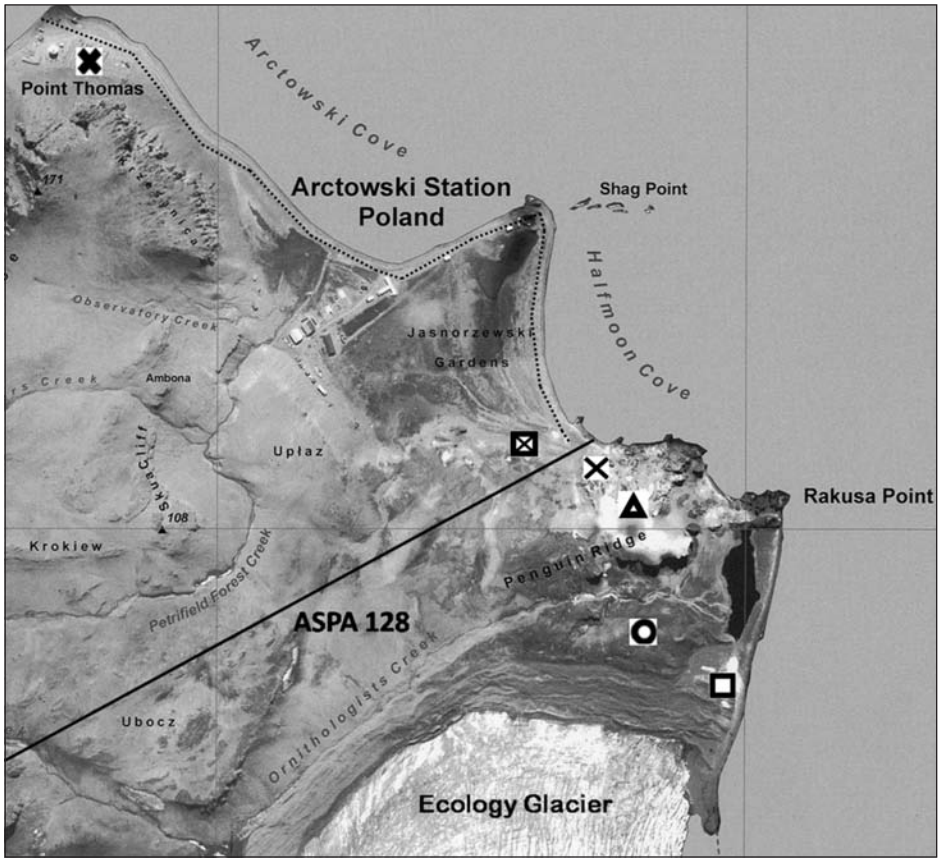
In 2007/2008 altogether 60 tourist ships brought 46 000 tourists to the Antarctic, plus over 28 000 crew and staff (www.iaato.org). It can be expected that both commercial tourists and private adventurers have high levels of travel mobility similar to expeditioners. Tourists congregate in small coastal areas rather than on land ice (Bölter and Stonehouse 2002). The sequence of sites visited over a short time period is often from warmer, higher biodiversity areas to cooler, lower biodiversity areas. Furthermore, Antarctic tourist expeditions commonly visit other high-latitude regions in North hemisphere within six months before departing for Antarctica. While some locations receive only a couple of visits per decade, the most popular ones may be visited even three times weekly throughout a short summer season (even 430 landing per site) (www.iaato.org).

Numerous investigators have reported, however, that tourists were responsible for consequences of wildlife disturbance, vegetation trampling, material imports and other impacts on the environment (Enzenbacher 1992). Such environmental impacts are generally transient, with most pressure on repeatedly-visited centres of attraction ashore (Kriwoken and Roots 2000).

A human impact on concentrations of birds and seals has been observed by many authors (Hemmings 1990; Young 1990, Salwicka and Stonehouse 2000, Boren *et. al.* 2002; Engelhard *et. al.* 2004). Repeated exposure to human activity can change the behavioural response of wildlife. Direct and incidental human impacts on animals, such as killing and maiming, poisoning (by lead batteries and baits for other species), entanglement in fishing lines, striking aerials, aircraft and helicopter overflights, fowl diseases, oiling, habitat modifications, disturbance of food chains, addiction to food sources (wastes and exotic introductions) and egg moving, are known and recorded (Hemmings 1990). This paper focuses on long-term influences of human presence on sensitive ecosystems in the vicinity of the Polish Antarctic Station *Arctowski*, in Admiralty Bay, King George Island, South Shetland Islands, West Antarctica.

Methods

Data presented here were gathered both from literature and from previously unpublished data collected by research programs based at the station. The involved area includes the *Arctowski* Station (62°09'41"S and 58°28'10"W) and the contiguous western shore of Admiralty Bay (Fig. 1). The station has been occupied year-round since it's founding in 1977. It has been visited by tourists from early 80ths. The nesting areas of birds in the vicinity of *Arctowski* are also thoroughly studied by the American researchers from the American ornithological Field Camp *Copacabana*. The number of tourists landing during austral summers and the number of expeditioners from summer and winter groups were collected. Regular monitoring of numbers of tourists visiting the station started in the 1991/1992 summer season and continued until 1996/1997, then resumed from 2006/2007 onward.



Penguin rookeries:
Adélie penguin (*Pygoscelis adeliae*) present △
Gentoo penguin (*Pygoscelis papua*): present □ abandoned ⊠
Chinstrap penguin (*Pygoscelis antarctica*) abandoned ×
Breeding groups of southern giant petrel (*Macronectes giganteus*): present ○ abandoned ✖
Tourist available path ····· ASPA 128 northern border ——

Fig. 1. The topographic map of the study area (fragment of Western shore of Admiralty Bay, King George Island: orthophoto map 1:10,000, Pudełko 2007).

Early observations of birds and seals in a study area around the station, extending from Point Thomas to Ecology Glacier, were recorded by Myrcha and Teliga (1980) and Jabłoński (1984, 1986), see Fig. 1. Total numbers of nesting birds in colonies were recorded during their breeding seasons (Jabłoński 1986; Sierakowski 1991; Rakusa-Suszczewski and Sierakowski 1993; Ciaputa and Sierakowski 1999). Pinnipeds were counted in their breeding groups in spring and in resting and moulting areas during summer (Myrcha and Teliga 1980; Rakusa-Suszczewski and Sierakowski 1993; Ciaputa 1996; Salwicka and Rakusa-Suszczewski 2002). Investigated penguin rookeries are situated in the area which in 1979 was designated as a

Site of Special Scientific Interest (SSSI No. 8) after proposal by Poland. From 2002 earlier category of this area was replaced by Antarctic Specially Protected Area 128 (ASPA 128) covering western shore of Admiralty Bay (Fig. 1).

Results and discussion

Arctowski Station is one of the most frequently visited research stations in the Antarctic region and has attracted tourists since it was established. In the 1992/1993 austral summer the station log book listed 32 visits and a total of 2996 tourists from cruise ships. By 1996/97 the number of tourist decreased to 1852 (Ciaputa and Salwicka 1997). In 2006/2007 the number of tourist vessels reached 27 and 5800 tourists landed, but in the following season the number of tourists fell to 3000, because of unusually bad weather and sea ice conditions. In 2008/2009 it increased again to 4700 (Figs 2 and 3).

All tourist visitors to *Arctowski* were seaborne, arriving in cruise ships carrying between 30 and 300 passengers of more than 25 nations. Duration of visits averaged between two and three hours. Most of the ships had left or were returning to Ushuaia or Punta Arenas in South America, and found *Arctowski* conveniently placed to be the first or final visit of the cruise. Passengers were brought ashore by inflatable boats in parties of 10 to 15, accompanied and closely supervised by guides (Ciaputa and Salwicka 1997; Stonehouse 1999).

During the last five summer seasons (2004–2009) the station log book listed on average two visits of private yachts with about 5 passengers on board per season. Accurate statistics of numbers of yachts with passengers and crew counts are very difficult to obtain at present. Many visits go unreported, and it is difficult to presume future levels of yacht activity in the Antarctic (Enzenbacher 1993) and thus their influence on environment.

Expeditions

Antarctic stations are typically located on ice-free coastal lands, which are also the only suitable habitats for most of the flora and fauna. Therefore, human habitation is concentrated in areas of high environmental sensitivity (Poland *et al.* 2003). Scientists support and military personnel have become most numerous in Antarctic region. Approximately 900 scientists and supporting staff wintered in Antarctica in 1985 and 3,000 were at work in the following austral summer (Stonehouse 1992). Antarctic Treaty data reveal that, in the 2008 winter season 111 stations, refuges and field camps in Antarctica had 1,094 personnel and 4,460 people were at work in the following austral summer (www.comnap.aq). It has never been doubted that Antarctic station operations have always been accompanied by local environmental distur-

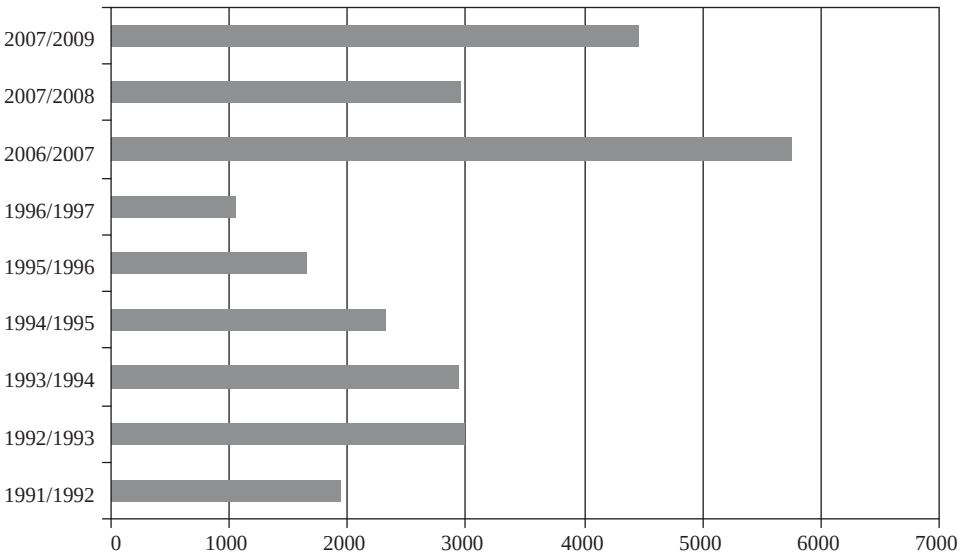


Fig. 2. Total number of tourists visiting *Arctowski* Station.

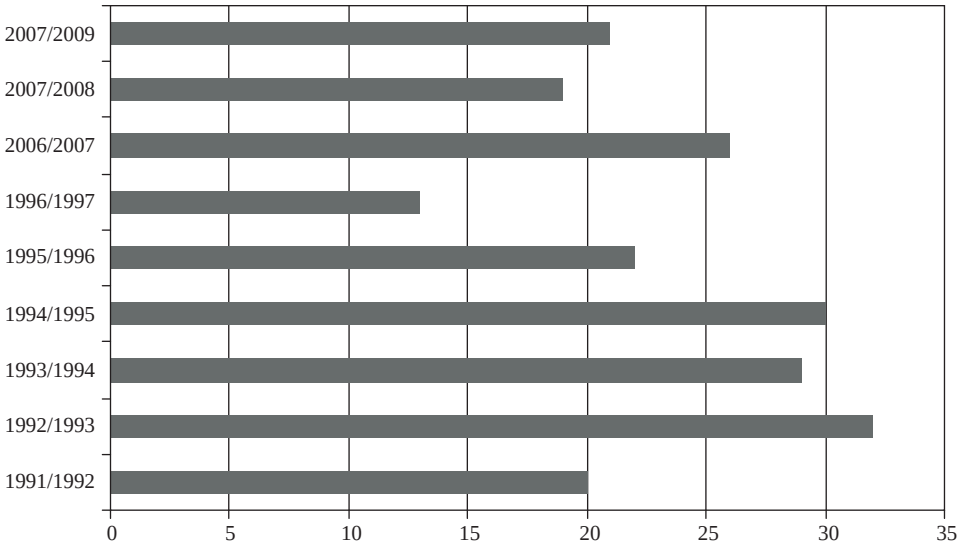


Fig. 3. Total number of tourist vessels visiting *Arctowski* Station.

bance. As a result of concentrated activities, such as power generation, waste disposal, vehicle use, fuel management, and airstrip and road construction, the areas around stations suffered much more human impact than other regions of Antarctica (Campbell *et al.* 1998). A substantial growth in scientific expeditions resulted in setting up numerous stations, settlements, camps and field refuges in Antarctica, many of which have had adverse influence on their surroundings (Olech 1991). There are a

few records of radionuclide or trace element contamination in the neighbourhood of big Antarctic Stations (Osyczka *et al.* 2007; Mietelski *et al.* 2008). More and more evidence has been found that the Antarctic is receiving a steady biological import from other parts of the world in various ways. Chown and Avenant (1992) have suggested that very few or no alien species are introduced by natural vectors. However, humans appear to be responsible for the dispersal of alien organisms as a result of such activities as importing poultry products, and introduction of non-indigenous plants (Olech 1991, 2003; Chwedorzewska 2008) and animals (Pugh 1997). Propagules are introduced by human activities at the station, including building activity and waste deposits, and affected by numbers of expedition members, size of cargoes, and frequencies of ship landings (Olech 1996).

However, impacts resulting directly or indirectly from scientific activities are not restricted to research stations. Since 1977 *Arctowski* has served as the logistic centre for Polish Antarctic operations. During 33 expeditions up to 2008/09, altogether 459 people have worked at the Station in one year cycle, whereas in summer – 733 people (Fig. 4), including some foreign scientists, mainly from Argentina, Belgium, Bulgaria, Canada, Chile, the Czech Republic, Germany, Hungary, Monaco, New Zealand, Peru, Russia, Spain, Switzerland, Ukraine, United Kingdom and USA. The largest teams worked in the summer seasons from 1978/79 to 1981/82 during the building of the Station, and during the 22nd expedition 1997/98, when the main building was renovated. Due to official record in a log book, during the total 33 expeditions, the average winter group reaches 14, and summer group – 8 people, altogether 22 in summer and winter. During the last 3 expeditions the

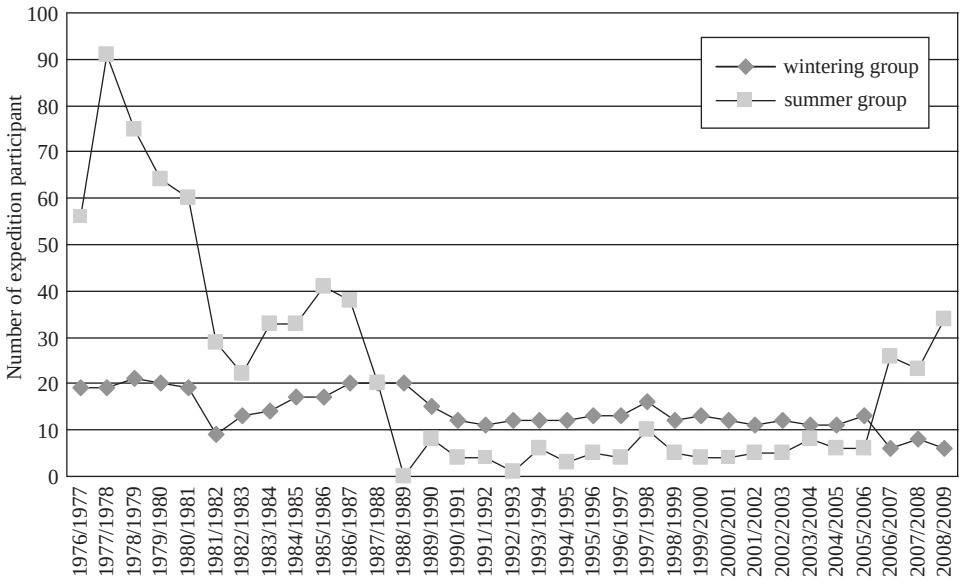


Fig. 4. Number of expeditioners staying at the *Arctowski* Station during following expeditions.

number of wintering people has decreased and the number of summer groups has increased significantly, with average 7 and 27 respectively (with a peak of 40 expeditioners in summer 2008/2009) (Fig. 4).

Although there is a significant number of tourists visiting *Arctowski* oasis, expeditioners remain there considerably longer and therefore have the opportunity to create considerably greater impact on the wildlife and environment. Scientific activity is concentrated mainly in the austral summer, during the period of thaw, which corresponds to breeding seasons of a number of indigenous species. This timing adds significantly to the likelihood of environmental damage (Stewart *et al.* 2005).

Arctowski Station is resupplied with necessary products once yearly in the austral summer or, if needed, in more than one spring and summer voyages. Cargo brought in annually between 1977 and 1990 varied from 36.5 to 8164.8 tons (Rakusa-Suszczewski and Krzyszowska 1991). During the last five expeditions the amount has stabilized at approximately 50 tons per year (Roszczyk, personal information).

Ecological constraints on birds and seals

Eleven breeding species of birds: Adélie penguin (*Pygoscelis adeliae*), gentoo penguin (*Pygoscelis papua*), chinstrap penguin (*Pygoscelis antarctica*), south polar skua (*Catharacta maccormicki*), brown skua (*Catharacta antarctica lonnbergi*), Antarctic tern (*Sterna vittata*), kelp gull (*Larus dominicanus*), pale-faced sheathbill (*Chionis alba*), southern giant petrel (*Macronectes giganteus*), Wilson's storm-petrel (*Oceanites oceanicus*), black-bellied storm petrel (*Fregetta tropica*) as well as five species of pinnipeds: four of Phocidae and one of Otariidae are encountered regularly in the vicinity of *Arctowski* Station. Presently, four species of Phocidae, pinnipeds: southern elephant seal (*Mirounga leonina*), Antarctic fur seal (*Arctocephalus gazella*), crabeater seal (*Lobodon carcinophagus*) and leopard seal (*Hydrurga leptonyx*) have their gathering (moulting, resting *etc*.) places in the *Arctowski* area (Presler 1980; Jabłoński *et al.* 1987; Sierakowski 1991; Lesiński 1993; Ciaputa 1996). Weddell seal (*Leptonychotes weddellii*) and southern elephant seal used to breed there (Woyciechowski 1980; Krzemiński 1981), at present only Weddell seal breeds occasionally. There have been also four recorded appearances of another pinniped, Ross seal (*Ommatophoca rossii*) between Point Thomas and Halfmoon Cove (Myrcha and Teliga 1980; Rakusa-Suszczewski and Sierakowski 1993).

Adélie penguin, gentoo penguin, chinstrap penguin

In 1978 the number of breeding pairs of the three pygoscelid penguins species in the vicinity of *Arctowski* Station was recorded as 11,561, including 10,140 nests

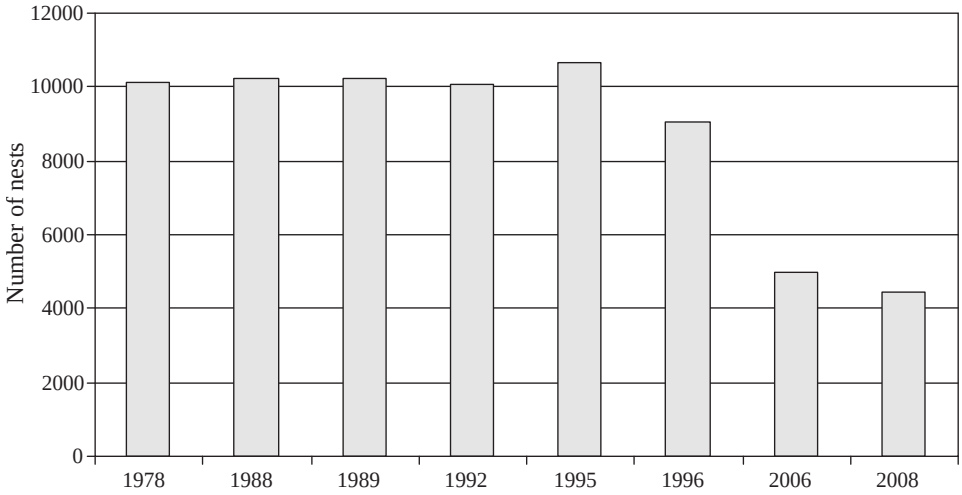


Fig. 5. The total number of nests of *Pygoscelis adeliae*.

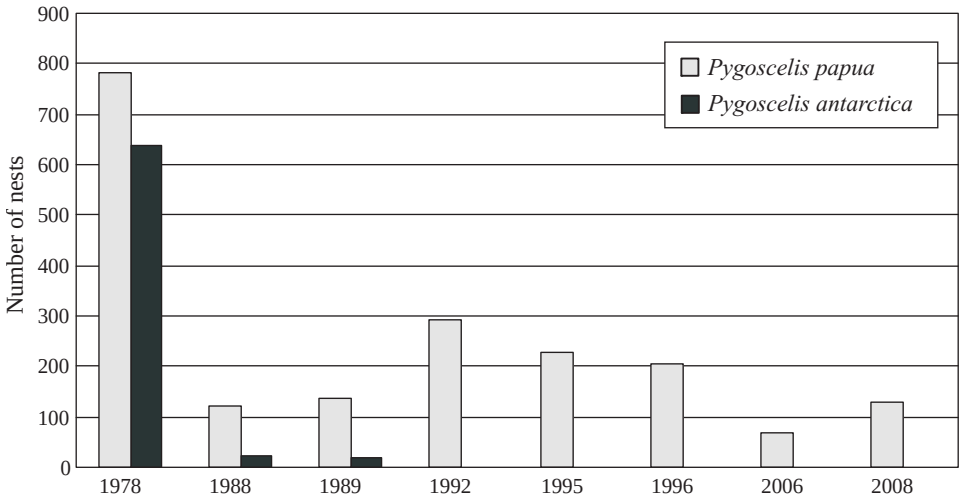


Fig. 6. The total number of nests of *Pygoscelis papua* and *Pygoscelis antarctica*.

of Adélie penguin, 638 nests of chinstrap, and 783 nests of gentoo penguin (Figs 5 and 6). Numbers have since declined during the thirty years of observations. In 2006 there were 4,471 nests of Adélie penguin, 1 of chinstrap, and 129 of gentoo penguin. The Adélie penguin population dropped by 55.9%; chinstrap penguin became practically extinct, and gentoo penguin decreased by 83.5%. In the whole ASPA 128, covering all penguin rookeries from the whole western shore of Admiralty Bay, the following trend in penguin populations was observed: number of breeding birds of chinstrap penguin dropped by 51.6% and Adélie penguin dropped by 52.8% comparing to 1996.

A different trend has been observed for gentoo penguin. While the number of breeding pairs of Adélie and chinstrap penguin is decreasing, population of gentoo in ASPA 128 has increased by 91.9% since 1996, but not in the vicinity of *Arctowski* (Figs 5, 6). In this area the number of nests decreased significantly (83.5%). The comparison of these results with trends in the penguin populations from the western shore of King George Bay (Antarctic Specially Protected Area 151) with practically no human impact suggest that these fluctuations are probably related to other factors (Angiel and Korczak 2008). It is not obvious if the disappearance of chinstrap penguin population from the breeding areas in the vicinity of *Arctowski* and the significant decrease of gentoo penguin population were caused by human impact. However two small groups of gentoo penguins close to the station have been visited often by station personnel also tourists and disappeared in the mid-to-late 1990s (Stonehouse, personal information). Moreover, penguin decline can be caused by higher concentration of skuas occuring around small penguin groups, which are unable to resist the predator attacks (Young 1990).

South polar skua, brown skua

Two species of skuas occur in the *Arctowski* area, brown skua and south polar skua, and both are sensitive to human activity. Trivelpiece *et al.* (1981) recorded that 90% of banded brown skua population in vicinity of *Arctowski* disappeared between 1977/78 and 1980/81 summer seasons. The loss may have been a natural phenomenon, but human agency cannot be excluded. Spoiled avian food products (eggs, egg powder and poultry meat) present a risk of introducing ex-

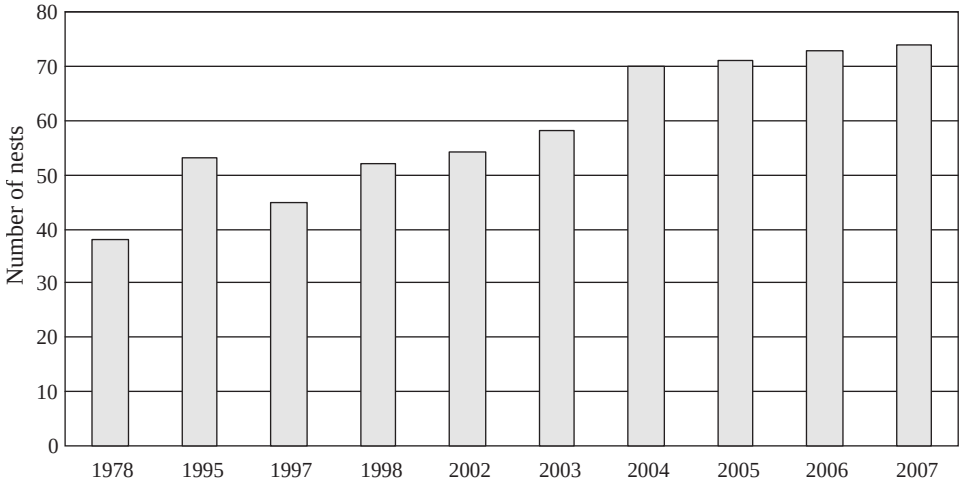


Fig. 7. The total number of nests of *Catharacta antarctica lonnbergi* and *Catharacta maccormicki.*

otic avian disorders when discarded. However nowadays in the vicinity of *Arctowski* the number of skua breeding pairs increased by 94% since 1978 (Fig. 7) which does not correspond with the tendencies in penguin populations in the investigated area. According to Johnston (1971), the decline of the Antarctic skua approximately coincides with the decline in the Adélie penguin population and this case is therefore considered under the effects of disturbance of existing food chains. (Hemmings 1990).

The obvious habituation of skuas to the presence of people has been observed. Birds have become more confident. While most Antarctic skua pairs do not rear their second chick, in the vicinity of the stations enhanced food availability may affect the survival of the second chick (Jouventin and Guillotin 1979). That was observed also at *Arctowski* Station; availability of food scraps from the stations allows birds to overwinter in these areas, whereas most other birds are absent during winter (Williams 1980). Skuas are long-lived birds, thus their reproductive rate is not high. (Ainley *et al.* 1984). Any factors which tend to decrease adult mortality could have serious implications for local populations. At *Arctowski* Station the skua population is very sensitive to human activity; that is evidenced by significant increase in number of these birds in this area.

Southern giant petrel

In spite of the data which have not shown significant differences in the nest numbers in 1978 comparing to 2006 the human impact on the southern giant petrel population was strongly marked. When *Arctowski* Station was opened, 37 nests were counted, mainly in the Point Thomas area, where a fuel tank was constructed. In the next few years the Point Thomas nests were reduced in number, the last one disappearing in 1991. Since then the breeding population within the *Arctowski* area has grown, reaching 32 nests in 2006. Southern giant petrel are easily disturbed in their nests and readily leave them when humans approach. Chronic human disturbance, such as the presence of nearby research stations (aircraft flights and continuous research activities) can cause population decline in the colony, due to the extremely timid nature of this species and its sensitivity to external conditions (Micol and Jouventin 2001; Nel *et al.* 2002; Woehler *et al.* 2003).

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). Ten years after summer season 1978/79, a 75% decrease of Antarctic tern population in investigated area was recorded by Sierakowski (1991). Wasilewski (1986) observed 135 nests of Wilson's storm petrel in 1979/80 and 121 nests in 1980/81, but there are no recent data concerning these both breeding bird species.

Pinnipeds

The human impact on pinnipeds in the vicinity of *Arctowski* Station concerns mainly breeding species of seals. Seals that only rest and moult in the area seem to be less sensitive. Two breeding species, southern elephant seal and Weddell seal, were present throughout the year in 1978 (Rakusa-Suszczewski and Sierakowski 1993). Weddell seal and southern elephant seal breeding areas close to *Arctowski* are easily accessible and regularly visited by both tourists and station personnel, for general interest and photography as well as scientific purposes.

Southern elephant seal

In Admiralty Bay southern elephant seal belongs to the most numerous seal species, breeding regularly (Salwicka and Rakusa-Suszczewski 2002). In January and the first half of February southern elephant seals were the most frequently encountered mammals on the coast of Admiralty Bay. On the entire western shore of the bay the number of individuals was fluctuating in different years (Fig. 8). January 1978 counts showed up to 300 animals from Point Thomas to Fur Seal Point, aggregating mainly in moulting groups, numbering from a few to dozens of individuals. In the vicinity of *Arctowski* Station the most numerous groups were observed at Halfmoon Cove at the edge of a penguin colony (about 30 and 45 mainly young animals with a predominance of males). A small reproductive colony was observed between Halfmoon Cove and Ecology Glacier (Myrcha and Teliga 1980). In subsequent summer seasons: 1995/96, 1999/2000 and 2002/003 only

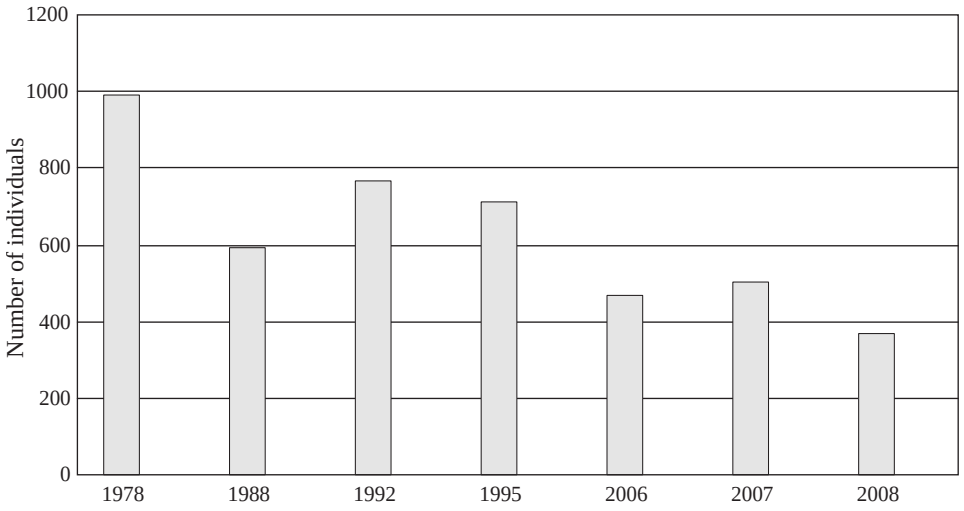


Fig. 8. The total number of individuals of *Mirounga leonina* on the whole western shore of Admiralty Bay.

one female with a pup was observed occasionally in this area. More recently no births have been recorded in this area, while the Blue Dyke and Patelnia Point breeding groups, situated about 10 km from *Arctowski*, with low human influences, are still in existence. Salwicka and Rakusa-Suszczewski's (2002) study of elephant seal population level in Admiralty Bay shows that it was stable from 1993 to 2000, in spite of fluctuations in the number of pups in different years. The highest numbers of individuals were noted in the area neighbouring the Bransfield Strait, the Blue Dyke and Patelnia Point oases. Salwicka and Stonhouse's (2000) study indicate that human disturbances can lead to reduced *apnoea* occurrence in southern elephant seals sleeping on land. Reduced *apnoea* occurrence in southern elephant seal on land, especially during reproduction, could be one of many reasons of this breeding area disappearing from Halfmoon Cove.

Weddell seal

In Admiralty Bay area Weddell seals occur in small numbers throughout the year. In summer they are found on the shore and in winter on the shore and also on sea-ice. In February 1978 in the present ASPA 128 area over 120 individuals were counted. The greatest number of Weddell seal was observed in the vicinity of *Arctowski* in early September. During the reproduction season 1977/78 seven females with newborn pups were noticed on the beach of Halfmoon Cove. Also during the 1977 winter (Myrcha and Teliga 1980) and in November 1976 (Müller-Schwarze *et al.*1978) some breeding Weddell seals were observed in the vicinity of the Station. In ASPA 128, in the period of 1994–2000, the total number of Weddell seals declined significantly (6±0.50) in comparison to the previous years 1988–1992 (11±0.60). According to Salwicka and Rakusa-Suszczewski (2002),

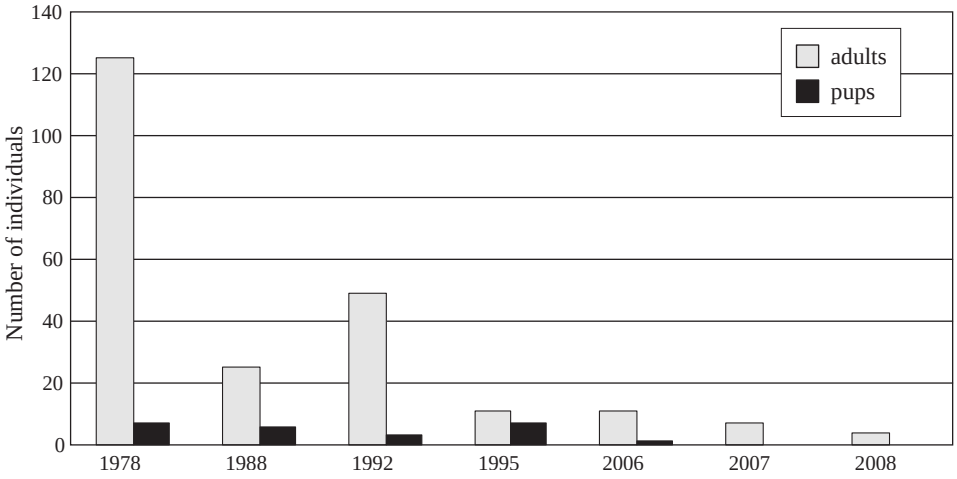


Fig. 9. The total number of individuals of *Leptonychotes weddellii* in the study area.

the highest numbers of pups were noted in 1988 and 1995 (6 and 7 pups respectively). From 1995 to 2000 the largest number of pups born was 3. From 2006 to 2008 just 1–3 adult individuals have been observed in this area, and once one female with pup (Fig. 9). Boren *et al.* (2002) suggested that seals show strong habituation to high levels of exposure to human activity. For example regularly visited lactating Weddell seals showed signs of habituation (Van Polanen *et al.* 2008). It does not agree with our observations that the number of Weddell seals dropped drastically. It may suggest a different factor affecting such population tendencies. Weddell seal total numbers in the whole ASPA128 were significantly lower in the years 1994–2000 and 2006–2008 than in the period 1988–1992.

Conclusions

During the thirty three expeditions to *Arctowski* Station the influence of human activity on the environment has been significant. Some elements of the biome seem to be more sensitive than others. For example there is evidence of disappearing of breeding areas of two penguin species (gentoo and chinstrap), one southern giant petrel, and of two species of pinnipeds: Weddell seal and southern elephant seal. The population of skuas, which have shown some indication of synanthropization, has proved strong human influence. Increase in these bird populations has been recorded in response to the station garbage. The impact of the humans may have induced changes of biotic factors influencing Antarctic animals and plants, like for example the presence of *Salmonella* sp. in the intestinal flora of the two gentoo penguin sampled populations in vicinity of the station (Dimitrov *et al.* 2009).

In spite of the consistent growth in the number of tourist visits, the research expeditioners' activity is crucial. Especially the number and mobility of summer groups seems to be the most influential factor exerting an impact on the environment.

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References

AINLEY D.G., MORRELL S.H. and WOOD R.C. 1984. Population studies of the south polar skua. *Antarctic Journal of the United States* 14: 167–168.

ANGIEL P. and KORCZAK M. 2008. Comparison of population size of penguins concerning present and archive data from ASPA 128 and ASPA 151 (King George Island). Arctic and Antarctic Per-

spectives in the International Polar Year. SCAR/IASC IPY. Open Science Conference. St. Petersburg, Russia. July 8th – 11th 2008. Abstract volume: 241.

BÖLTER M. and STONEHOUSE B. 2002. Uses, Preservation, and Protection of Antarctic Coastal Regions. *Ecological Studies* 154: 393–407.

BOREN L.J., GEMMELL N.J. and BARTON K.J. 2002. Tourist disturbance on New Zealand fur seals *Arctocephalus forsteri*. *Australian Mammalogy* 24: 85–95.

CAMPBELL I.B., CLARIDGE G.G.C. and BALKS M.R. 1994. The effect of human activities on moisture content of soil and underlying permafrost from the McMurdo Sound region, Antarctica. *Antarctic Science* 6: 307–314. http://dx.doi.org/10.1017/S0954102094000477

CAMPBELL I.B., CLARIDGE G.G.C. and BALKS M.R. 1998. Short- and long-term impacts of human disturbances on snow-free surfaces in Antarctica. *Polar Record* 34: 15–24. http://dx.doi.org/10.1017/S0032247400014935

CIAPUTA P. 1996 Numbers of pinnipeds during 1994 in Admiralty Bay, King George Island, South Shetland Islands. *Polish Polar Research* 17: 239–244.

CIAPUTA P. and SALWICKA K. 1997. Tourism at Antarctic "Arctowski" Station 1991–1997: policies for better management. *Polish Polar Research* 18: 227–239.

CIAPUTA P. and SIERAKOWSKI K. 1999. Long-term population changes of Adelie, chinstrap, and gentoo penguins in the regions of SSSI No. 8 and SSSI No. 34, King George Island, Antarctica. *Polish Polar Research* 20: 355–365.

CHOWN S.L. and AVENANT N. 1992. Status of *Plutella xylostella* at Marion I. six years after its colonization. *South African Journal of Antarctic Research* 22: 37–40.

CHWEDORZEWSKA K.J. 2008. *Poa annua* L. in Antarctic – searching for the source of introduction. *Polar Biology* 31: 263–268. http://dx.doi.org/10.1007/s00300-007-0353-4

CURRY C.H., MCCARTHY J.S., DARRAGH H.M., WAKE R.A., CHURCHILL S.E., ROBINS A.M. and LOWEN R.J. 2005. Identification of an agent suitable for disinfecting boots of visitors to the Antarctic. *Polar Record* 41: 39–45. http://dx.doi.org/10.1017/S0032247404003961

DIMITROV K., METCHEVA R. and KENAROVA A. 2009. *Salmonella* presence – an indicator of direct and indirect human impact on Gentoo in Antarctica. *Biotechnology & Biotechnological Equipment* 23: 246–249.

ENGELHARD G., VAN DEN HOFF J., BROEKMAN M., BAARSPUL A.N.J., FIELD I., BURTON H.R. and REIJNDERS P.J.H. 2004. Mass of weaned elephant seal pups in areas of low and high human presence. *Polar Biology* 24: 244–251. http://dx.doi.org/10.1007/s003000000204

ENZENBACHER D.J. 1992. Tourists in Antarctica: numbers and trends. *Polar Record* 28: 17–22. http://dx.doi.org/10.1017/S0032247400020210

ENZENBACHER D.J. 1993. Antarctic tourism: 1991/92 season activity. *Polar Record* 29: 240–242. http://dx.doi.org/10.1017/S003224740001857X

HEMMINGS A.D. 1990 Human impacts and ecological constraints on skuas. *In*: K.R. Kerry and G. Hempel (eds) *Antarctic Ecosystems: Ecological Change and Conservation*. Springer-Verlag, Berlin: 224–230.

JABŁOŃSKI B. 1984. Distribution, number and breeding preferences of penguins in the region of the Admiralty Bay (King George Islands, South Shetland Islands) in the season 1979/80. *Polish Polar Research* 5: 5–16.

JABŁOŃSKI B. 1986. Distribution, abundance and biomass of a summer community of birds in the region of the Admiralty Bay (King George Islands, South Shetland Islands, Antarctica) in 1978/79. *Polish Polar Research* 7: 217–260.

JABŁOŃSKI B. 1995. Distribution, abundance and biology of the Antarctic Tern, *Sterna vittata* Gmelin, 1789 on King George Island (South Shetland Islands). *Acta Zoologica Cracoviensia* 38: 399–460.

JABŁOŃSKI B., KRZEMIŃSKI W. and ZDZITOWIECKI K. 1987. Distribution and number of fur seals, *Arctocephalus gazella* (Peters, 1875) of King George Island (South Shetland Islands). *Acta Zoologica Cracoviensia* 30:119–136.

JOHNSTON B.R. 1971. Skua numbers and conservation problems at Cape Hallett, Antarctica. *Nature* 231: 468. http://dx.doi.org/10.1038/231468a0

JOUVENTIN P. and GUILLOTIN M. 1979. Socio-écologie du skua antarctique à Pointe Géologie. *La Terre et la Vie – Revue d'Écologie* 33: 109–127.

KRIWOKEN L. and ROOTES D. 2000. Antarctic tourism: Tourism on ice: environmental impact assessment of Antarctic tourism. *Impact Assessment and Project Appraisal* 18: 138–150. http://dx.doi.org/10.3152/147154600781767538

KRZEMIŃSKI W. 1981. Southern elephant seal (*Mirounga leonina* L.) of Admiralty Bay (King George Island, South Shetland Islands). Its numbers and activity during the moulting season in summer 1978/1979. *Polish Polar Research* 2: 143–152.

MICOL T. and JOUVENTIN P. 2001. Long-term population trends in seven Antarctic seabirds at Pointe Geologie (Terre Adélie). Human impact compared with environmental change. *Polar Biology* 24:175–185. http://dx.doi.org/10.1007/s003000000193

LESIŃSKI G. 1993. Monitoring of birds and pinnipedians on King George Island (South Shetland Islands) in 1989/90. *Polish Polar Research* 14: 75–89.

MIETELSKI J.W., OLECH M.A., SOBIECH-MATURA K., HOWARD B., GACA P., ZWOLAK M., BŁAŻEJ S. and TOMANKIEWICZ E. 2008. ^{137}Cs, ^{40}K, ^{238}Pu, $^{239+240}$Pu and ^{90}Sr in biological samples from King George Island (Southern Shetlands) in Antarctica. *Polar Biology* 31: 1081–1089. http://dx.doi.org/10.1007/s00300-008-0449-5

MÜLLER-SCHWARZE D., WALTZ E.C., TRIVIELPIECE W. and VOLKMAN N.J. 1978. Breeding status of southern elephant seals at King George Island. *Antarctic Journal of the United States* 13: 157–158.

MYRCHA A. and TELIGA K. 1980. Observations of pinnipedian mammals in the vicinity of *Arctowski* Station (King George Island in 1978). *Polish Polar Research* 1: 117–126.

NEL D.C., RYAN P.G., CRAWFORD R.J.M., COOPER J. and HUYSER O.A.W. 2002. Population trends of albatrosses and petrels at sub-Antarctic Marion Island. *Polar Biology* 25: 81–89.

OLECH M. 1991. Preliminary observations on the content of heavy metals in thalli of *Usnea antarctica* Du Rietz (Lichens) in the vicinity of the "H. Arctowski" Polish Antarctic Station. *Polish Polar Research* 12: 129–131.

OLECH M. 1996. Human impact on terrestrial ecosystems in west Antarctica. *Proceedings of the NIPR Symposium on Polar Biology* 9: 299–306.

OLECH M. 2003. Expansion of alien plant *Poa annua* L. in the vicinity of the Henryk Arctowski Station – a consequence of climate change? XXIX International Polar Symposium *The functioning of polar ecosystems as viewed against global environmental changes.* Kraków: 89–90.

OSYCZKA P., DUDKIEWICZ E.M. and OLECH M. 2007. Trace elements concentrations in selected moss and lichens species collected within Antarctic research stations. *Polish Journal of Ecology* 55: 39–48.

VAN POLANEN P.T., GIESE M. and HINDELL M. 2008. A preliminary investigation of the effect of repeated pedestrian approaches to Weddell seals (*Leptonychotes weddellii*). *Applied Animal Behavior Science* 112: 205–211. http://dx.doi.org/10.1016/j.applanim.2007.07.005

POLAND J.S., RIDDLE M.J. and ZEEB B.A. 2003. Contaminants in the Arctic and the Antarctic: a comparison of sources, impacts, and remediation options. *Polar Records* 39: 369–383. http://dx.doi.org/10.1017/S0032247403002985

PRESLER P. 1980. Phenological and physiographical observations carried out during the first wintering at the *Arctowski* Station in 1977. *Polish Archives of Hydrobiology* 27: 245–252.

PUDEŁKO R. 2007. Western shore of Admiralty Bay, King George Island: orthophoto map 1:10,000. Department of Antarctic Biology, Warsaw.

PUGH P.J.A. 1997. Acarine colonisation of Antarctica and the islands of the Southern Ocean: the role of zoochoria. *Polar Record* 33: 113–122. http://dx.doi.org/10.1017/S0032247400014431

RAKUSA-SUSZCZEWSKI S. and KRZYSZOWSKA A. 1991. Assessment of the environmental impact of the "H. Arctowski" Polish Antarctic Station (Admiralty Bay, King George Island, South Shetland Islands). *Polish Polar Research* 12: 105–121.

RAKUSA-SUSZCZEWSKI S. and SIERAKOWSKI K. 1993. Pinnipeds in Admiralty Bay, King George Island, South Shetlands (1988–1992). *Polish Polar Research* 14: 441–454.

RIFFENBURGH B. 1998. Impact on the Antarctic environment: tourism vs. government programmes. *Polar Record* 34: 193–196. http://dx.doi.org/10.1017/S0032247400025651

SALWICKA K. and RAKUSA-SUSZCZEWSKI S. 2002. Long-term monitoring of Antarctic pinnipeds in Admiralty Bay (South Shetlands, Antarctica). *Acta Theriologica* 47: 443–457.

SALWICKA K. and STONEHOUSE B. 2000. Visual monitoring of heartbeat and respiration in Antarctic seals. *Polish Polar Research* 21: 189–197.

SIERAKOWSKI K. 1991. Birds and mammals in the region of SSSI No. 8 in the season 1988/89 (South Shetlands, King George Island, Admiralty Bay). *Polish Polar Research* 12: 25–54.

STEWART E.J., DRAPER D. and JOHNSTON M.E. 2005. A review of tourism research in the polar regions. *Arctic* 58: 383–394.

STONEHOUSE B. 1992. Monitoring shipborne visitors to Antarctica: a preliminary field study. *Polar Record* 28: 213–218. http://dx.doi.org/10.1017/S0032247400020672

STONEHOUSE B. 1994. Tourism and protected areas. *In*: R.I.L. Smith, D.W.H. Walton and P.R. Dingwall (eds) *Developing the Antarctic Protected Area System.* IUCN, Gland: 79–84.

STONEHOUSE B. 1999. Antarctic shipborn tourism: facilitation and research at *Arctowski* Station, King George Island. *Polish Polar Research* 20: 65–75.

TRIVELPIECE W., BUTLER R.G. and VOLKMAN N. 1981. Pygoscelid penguins of Admiralty Bay. *Antarctic Journal of United States* 16: 150–151.

WASILEWSKI A. 1986 Ecological aspects of the breeding cycle in the Wilson's storm petrel, *Oceanites oceanicus* (Kuhl) at King George Island (South Shetland Islands, Antarctic). *Polish Polar Research* 7: 173–216.

WILLIAMS A. J. 1980. Aspects of breeding biology of the subantarctic *skua* at Marion Island. *Ostrich* 51: 160–167.

WOEHLER E.J., RIDDLE M.J. and RIBIC C.A. 2003. Long-term population trends in southern giant petrels in East Antarctica. *In*: A.H.L. Huiskes, W.W.C. Gieskes, J. Rozema, R.M.L. Schorno, S.M. Van der Vies and W.J. Wolff (eds) *Antarctic Biology in a Global Context*. Backhuys Publishers, Leiden: 290–295.

WOYCIECHOWSKI M. 1980. Numbers and activity of Weddell seal (*Leptonychotes weddelli* Lesson) in the Admiralty Bay (King George Island) in summer 1978/1979). *Polish Polar Research* 1: 207–216.

YOUNG E.C. 1990. Long-term stability and human impact in Antarctic Skuas and Adélie Penguins. *In*: K.R. Kerry and G. Hempel (eds) *Antarctic Ecosystems: Ecological Change and Conservation*. Springer-Verlag, Berlin: 231–236.

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