Proc. NIPR Symp. Polar Biol., 9, 299–306, 1996

HUMAN IMPACT ON TERRESTRIAL ECOSYSTEMS IN WEST ANTARCTICA

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Abstract: Examples of synanthropization of flora in the South Shetland Islands (West Antarctica) are presented. Investigations on man's impact were carried out between 1986 and 1993. Human impact on plant cover takes place in two parallel processes: some species (plantae hemerophobae) decrease their geographical range, as a result of direct and indirect habitat destruction; while others extend their area of occurrence (plantae hemerophilae) due to man's activity. The latter process is a consequence of introduction of anthropophytes (*e.g. Lecidella elaeochroma, Lecanora symmicta* and *Poa annua*) or creation of man-made habitats suitable for the native species (apophytes) colonization (*e.g. Muriella terrestris, Prasiola crispa, Acarospora macrocyclos, Amandinea coniops, Caloplaca citrina, C. sublobulata, Physcia caesia, Xanthoria candelaria* and *Tortula grossiretis*).

1. Introduction

With increasing human activity in Antarctica the impact on terrestrial ecosystems has become increasingly more visible; it is reflected especially by changes in vegetation and in geographical ranges of several species. Little attention has hitherto been paid to the problem of native flora synanthropization— in literature only fragmentary data may be found (LINDSAY, 1977; EDWARDS, 1979; LONGTON, 1988; APTROOT and VANDER, KNAAP, 1993; OLECH, 1989). More attention has been focused on the problems of changes in natural ecological conditions, *e.g.* due to introduction of anthropogenic macroelements, and to the effect of local contamination by heavy metals (MEANHAUT *et al.*, 1979; MOLSKI *et al.*, 1981; PĘCHEREWSKI, 1987; OLECH, 1991; OLECH *et al.*, 1993).

2. Study Area and Methods

2.1. Study area

The investigations were carried out in West Antarctica in the region of the South Shetlands Islands, mainly on King George Island, and also on Deception, Livingston and Greenwich (Fig. 1).

These islands are situated in the oceanic climate of Antarctica. The mean annual temperature is -1.8°C; yearly precipitation exceeds 500 mm (RAKUSA-SUSZCZEWSKI *et al.*, 1993).

The islands, composed mainly of volcanic rocks, are 90% covered with ice. Vegetation develops only in coastal oases and on nunataks. The plant species composition is characteristic of polar deserts. As in all of West Antarctica, cryptogams

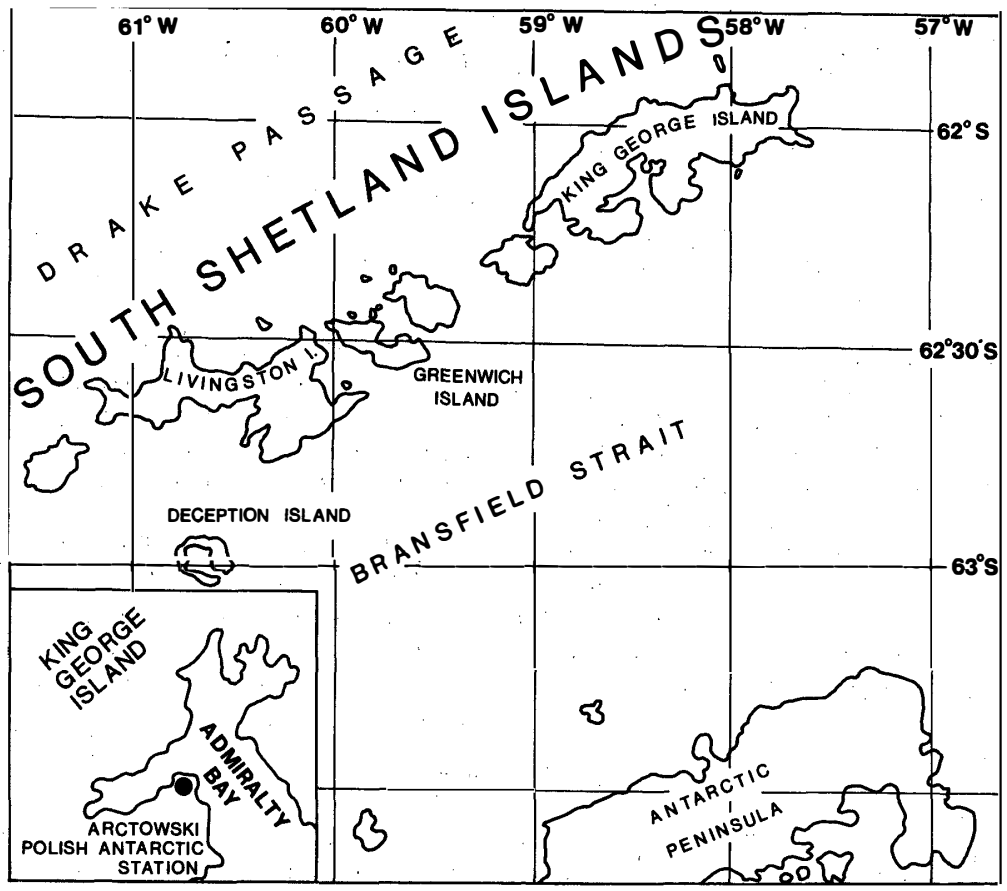

Fig. 1. South Shetland Islands.

dominate in flora and vegetation (SMITH, 1984; LONGTON, 1988; OLECH, 1989, 1993). The area is almost completely deprived of phanerogams: here only 2 native species occur, *i.e. Deschampsia antarctica* and *Colobanthus quitensis.*

Rocks are the main natural site typical for lichens and bryophytes, as well as soil and decaying remnants of dead plants. Algae occur on soil, bryophytes and rocks, but they predominantly colonize streams and pools.

2.2. History of man's influence on the islands

Following the discovery of the South Shetland Islands in 1819, which is attributed to William Smith, American, British and Spanish hunters of eared seal and seals became active. By the end of the 19th century they were replaced by whalers. The whaling industry developed very dynamically, especially in the 1920's. It had, at the beginning, a coastal character—hunted whales were towed to shore, where on beaches their fat was melted. From that period (which was an example of cruel man's wasteful exploitation) huge amounts of whale bones lying on the shores of the Southern Shetlands are dated. Cast iron boilers or kilns, in which fat was melted, are also remnants of that time. After hunters, scientific expeditions on the South Shetlands appeared. After an initial period of small wooden huts, stationary Antarctic bases began to be established. Now, there are several all-year stations here; on King George Island, an airport and communication infrastructure are to be built.

2.3. Methods

Investigations on man's impact were carried out by the author during three Polish Antarctic expeditions of the Polish Academy of Sciences to Arctowski Station (1986–88, 1989/90, and 1991–1993). The observations were concentrated in places of man's enhanced activity (past and present): whaling, all-year bases, transportation, tourism. Main attention was focused on monitoring the spread of alien species introduced by man (anthropophytes), and also much attention was devoted to investigation of colonization of artificial sites by native flora (apophytes). Permanent plots established at the beginning of the study period (1987) were mapped and photographed. The spreading of anthropophytes is displayed on cartograms.

3. Results

3.1. Introduction of alien species

Some species of alien origin were found in the area investigated (Livingston, King George Island), introduced unintentionally. There were among them lichens, *e.g. Lecidella elaeochroma* (Ach.) M.Choisy and *Lecanora symmicta* (Ach.) Ach., occurring on wood (OLECH, 1989). They are an example of transient encroachment in these regions on a substrate (building material). The shifting of these species into natural habitats has not been observed.

Another example is the cosmopolitan grass *Poa annua* L. (Fig. 2), which spreads and inhabits areas of the Arctowski oasis, where the Arctowski Polish Polar station is situated (King George Island, Admiralty Bay region). The species was observed for the first time in the summer of 1985/86 (oral communication from the participants of the 10th Polish Expedition); there were some plants in front of the entrance to the living quarters (in hollows of the metal grid used for cleaning shoes). During the subsequent

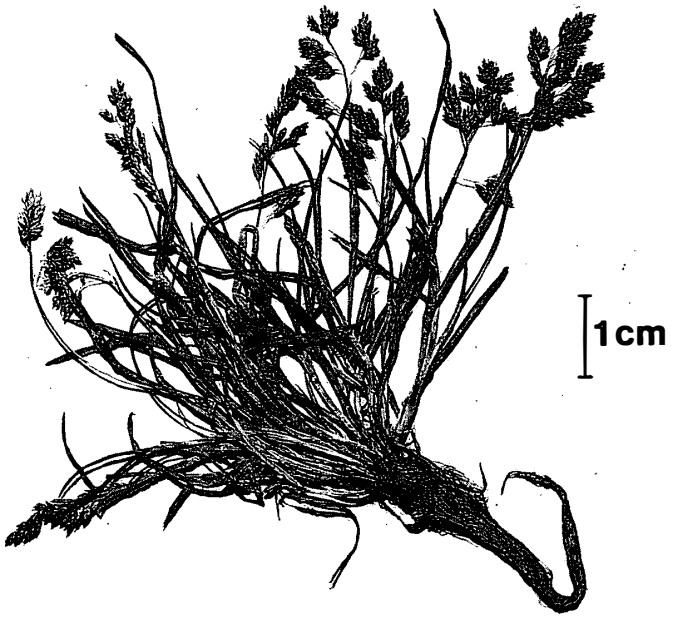

Fig. 2. Poa annua *L. (King George Island, Arctowski Station, near glasshouse, 22 January 1987, M. OLECH).*

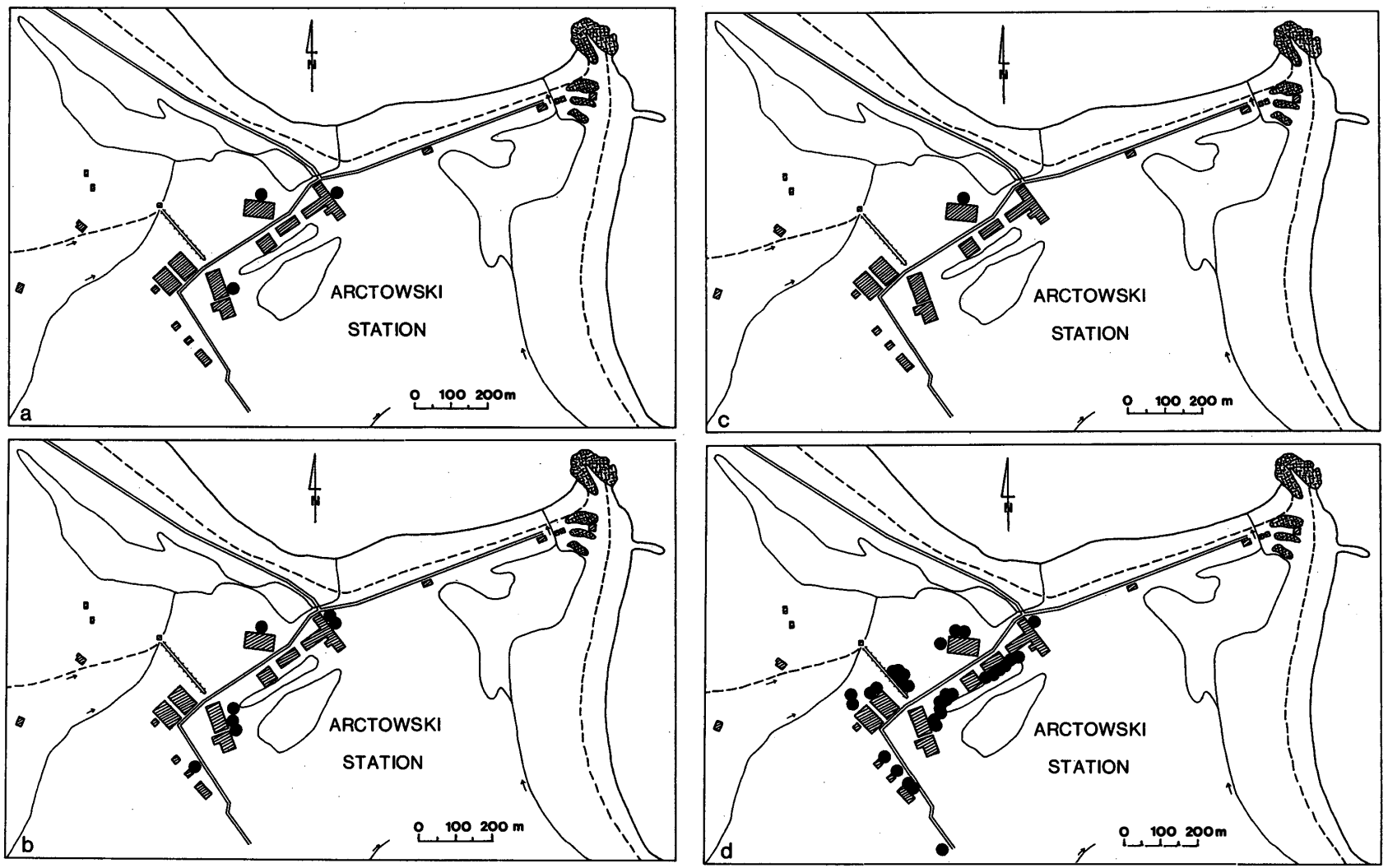

Fig. 3. Locations of grass **Poa annua** *L. in Arctowski Station in years. (a) 1986/87, (b) 1987/88, (c) 1989/90, (d) 1991/92.*

Table 1. Provisional list of apophytes from the South Shetland Islands.

Taxon	Whale bones	Wood	Rusty cast iron
Cyanophyta			
Schizothrix funiculus WORONICHIN	+		
Chlorophyta			
Muriella terrestris BOYE PETERSON	+		
Prasiola crispa (LIGHTF.) MENEGH	+	+	+
Pseudococcomyxa simplex (MAINX) FOTT	+		
Chloricitis sp.	+		
Chlorosarcina sp.	+		
Lichenes			
Acarospora macrocyclos VAIN.	+	+	
Amandinea coniops (WAHLENB. in ACH.) [M. CHOISY ex] SCHEID et H. MAYRH.	+		+
A. petermannii (HUE) MATZER, MAYRH. et SCHEID.	+		
Caloplaca austroshetlandica (ZAHLBR.) OLECH et SØCHTING		+	
C. cirrochrooides (VAIN.) ZAHLBR.	+	+	
C. citrina (HOFFM.) TH. FR.	+		+
C. coralligera (HUE) ZAHLBR.		+	
C. regalis (VAIN.) ZAHLBR.	+		
C. sublobulata (NYL.) ZAHLBR.	+	+	+
C. tenuis ØVST.	+		+
Haematomma erythromma (NYL.) ZAHLBR.	+	+	
Lecania brialmontii (VAIN.) ZAHLBR.	+		
L. gerlachei (VAIN.) ZAHLBR.	+		
Lecanora dispersa (PERS.) SOMMERF.	+	+	+
Physcia caesia (HOFFM.) FURNR.	+	+	+
Ph. dubia (HOFFM.) LETTAU	+		
Ph. wainioi RASANEN		+	
Rhizoplaca aspidophora (VAIN.) REDON	+	+	+
R. melanophtalma (RAM. in LAM. et DC) LEUCK. et POELT		+	+
Thelenella antarctica (LAMB.) ERIKSSON	+		+
Turgidosculum complicatulum (NYL.) KOHLM. et KOHLM.	+		+
Usnea antarctica DU RIETZ		+	+
Xanthoria candelaria (L.) TH. FR.		+	+
Musci			
Drepanocladus uncinatus (HEDW). WARNST.	+		
Tortula grossiretis CARD.	+		

years an increase in number of localities was observed (Fig. 3a–d) until summer of 1989/90 when *P. annua* was noted only in one locality (beside a glasshouse). In 1991/92 a sudden increase in number of localities and a strong spreading of the grass was observed. The observations on permanent plots showed a tremendous increase in number of individuals in populations under study (even to 150 in one spot between a warehouse and pond), forming a dense mat.

Poa annua colonizes places changed by man, where the natural vegetation was destroyed. It has not been found hitherto in natural communities outside the station. It prefers sites sheltered from wind (depressions, alongside buildings and the dump, at the bank of a pond), and also at sites of winter snowbeds. It is worthy to note that a factor or condition facilitating colonization of the grass is disturbance of soil structure by man, *e.g.* earthworks, old caterpillar tracks, etc. Further detailed observations, especially in permanent plots, have been continued.

3.2. Native species colonizing in newly created sites (apophytes)

The colonization of several sites of anthropogenic origin, *e.g.* on bones of slaughtered whales, wood, cast iron, glass, fabric, skin, etc., was found.

The most important substrata for development of native apophytic flora are whale bones, especially discs. The richest and the most diversified flora were found on the bones (Table 1). Species coming from the near vicinity, predominantly epilithic ones of seashore cliffs, were established here. The most important are lichens, *e.g. Caloplaca cirrochrooides, Thelenella anatrctica* and *Lecanora dispersa.* Blue-green algae, green-algae (Table 1), and mosses were also found here.

In the treeless landscape of Antarctica, wood is especially an atypical site created by man. This type of substrate is delivered mainly by boats and wrecks, abandoned Antarctic bases, huts of hunters, and elements of various wooden devices formerly serving for field investigations. There may also be planks, other construction materials broken np by wind or sea action. Wood is colonized mainly by an alga, *Prasiola crispa,* and lichens appear after a longer time. Here, the most often occurring species were: *Rhizoplaca melanophtalma, Rh. aspidophora, Amandinea coniops, Usnea antarctica,* or found hitherto among apophytes only on wood—*Caloplaca coralligera.* These are species for which natural substrata are rocks, rarely mosses and soil.

On rusted cast iron elements of kilns or boilers which had been abandoned for many years some species of lichens were found, such as *Caloplaca sublobulata, C. citrina, C. tenuis, Rhizoplaca melanophtalma, Thelenella antarctica,* and others, as well as the algae *Prasiola crispa.* All species occurring here are epilithics of natural sites.

3.3. Changes in natural conditions in effect of anthropogenic enrichment with macroelements

The typical example of such phenomenon is *Prasiola crispa,* a nitrophilous green-alga *(Chlorophyta).* It is a species colonizing aquatic and terrestrial biotopes enriched in minerals by birds and seals. A sudden spreading of the species has been observed in recent years in locations with enhanced human activity. This is especially visible on soil enriched with minerals (mainly nitrogen) due to accumulation of organic wastes around buildings in Antarctic stations.

4. Discussion

Antarctica is regarded as a region in which ecosystems hardly changed. Hence, the materials and observations coming from this area are often treated as a reference point in studies on environmental global change. On the other hand, as expanding human activity has an ever growing influence on Antarctic ecosystems, the influence of anthropogenic pressure upon the polar environment and organisms which inhabit it is more clearly seen. First, it may be found in changes in vegetation, especially in flora. The influence of human activity is reflected in two parallel processes: declining (plantae hemerophobae) and spreading (plantae hemerophilae) of plants. The decline of plants and diminishing of their geographical ranges is affected by direct destruction of plants or by devastation of their sites. Here should be mentioned the destruction of vegetation

cover by construction of polar stations, roads, airports, etc., and also by running over by vehicles or trampling by tourists. Also, plant collecting is of great importance; especially prone to this type of destruction are lichens, mainly the massive species of *Usneas,* collected as "souvenirs". The preparing of lichen (and of other groups of species) collections by amateurs has also affected the Antarctic tundra badly.

Human impact is also reflected in species colonization by anthropophytes, often in an unintentional way, encroaching here from other areas of the Earth (*e.g.* South America). The best example of a naturalized anthropophyte is the above mentioned *Poa annua,* transported to the Arctowski Station probably by boot dust (as it is proved by its first locality). The observed increase of its range in recent years might be, on one hand, a result of climate warming (during the past 10 years air temperature has risen by 0.2–0.6°C—RAKUSA-SUSZCZEWSKI *et al.,* 1993), and on the other, the effect of microsites created by man (digging the soil improves aeration, destroys natural vegetation cover, limits competition, etc.).

It is worthy to note other examples of potential colonizers in Antarctica brought in as dust on equipment and boots of expeditioners as described by BROADY and SMITH (1994).

Man's influence is also manifested by the creation of easy access to secondary sites for native species (apophytes), which increases their geographical ranges. There are many examples of such species in West Antarctica, mainly among lichens (Table 1). An especially high percentage of apophytes in Antarctic flora is observed in areas where man's activity has a longer history (APTROOT and VAN DER KNAAP, 1993; OLECH, 1994). Among apophytes, a high percentage is maintained by nitrophilous species (*e.g., Prasiola crispa, Caloplaca sublobulata, C. citrina, Physcia caesia, Rhizoplaca aspidophora* and others).

It is also worth-while to pay attention to the role of nutrients of anthropogenic origin in colonizing processes in Antarctica. Domestic sewage is a frequent source (KRZESZOWSKA, 1990). On soils fertilized with wastes a mass occurrence of *e.g. Prasiola crispa,* which may serve as an indicator species, is found.

Examples of anthropophytes and apophytes in the South Shetlands given here prove the ongoing synanthropization of Antarctic vegetation and flora. The scale of the phenomenon is not as wide as in other regions of the world; however, it should be remembered that it concerns the relatively small areas free of ice.

The proper evaluation of effects of man's activity is crucial for the unique ecosystems of the region. It concerns mainly vegetation, especially vegetgtion that recovers slowly and with difficulty in polar circumstances.

Acknowledgements

I am very grateful to Prof. Teresa MROZIŃSKA for algae determinations, and to Maciej WAYDA, M. Sc. for checking of *Poa annua* identifications.

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(Received March 27, 1995; Revised manuscript accepted August 28, 1995)