G. Schernewski & N. Löser (eds.): Managing the Baltic Sea.
Coastline Reports 2 (2004), ISSN 0928-2734
S. 139 - 147

Plant diversity dynamics on dunes of Swina Gate Barrier: a largely undisturbed accumulative coast

Ralf Grunewald[1] and Tomasz A. Łabuz[2]

[1] Institute of Aquatic Ecology, University of Rostock
[2] Institute of Marine Sciences, University of Szczecin

Abstract

The southern Baltic sandy coast areas are highly dynamic and under continuous natural and manmade change. Today complex dune habitats are rare and more and more affected by coastal defence measures and recreational activities. Natural or almost natural dune environments exist only in a few places. One of them is the middle part of Swina Gate Barrier on Wolin Island (Poland) where typical plant communities in different stages of vegetational succession and dune development can be found. Five dunal ridges can be observed in the central part of the barrier. The influence of human activities in the vicinity of the towns of Świnoujście and Międzyzdroje can clearly be seen, but the aim of this study was to survey and document undisturbed plant communities and dune dynamics. It could be shown that plants closely reflect the ecological conditions of the dunes creating a number of distinctly different habitats with mosses and lichens playing an important role in the different stages of succession. Sand accumulation is initiated and enhanced by psammophilous plants on the upper beach whereas a complete plant cover on older dunes will, e.g., result in a higher accumulation of humus. Sand accumulation, plant-cover and dune development depend on a continuous sand supply from the see and can be seen as ongoing processes compared to the more abrupt changes caused by heavy storms. Future studies will aim at comparing undisturbed sites with sites disturbed by recreational activities.

1 Introduction

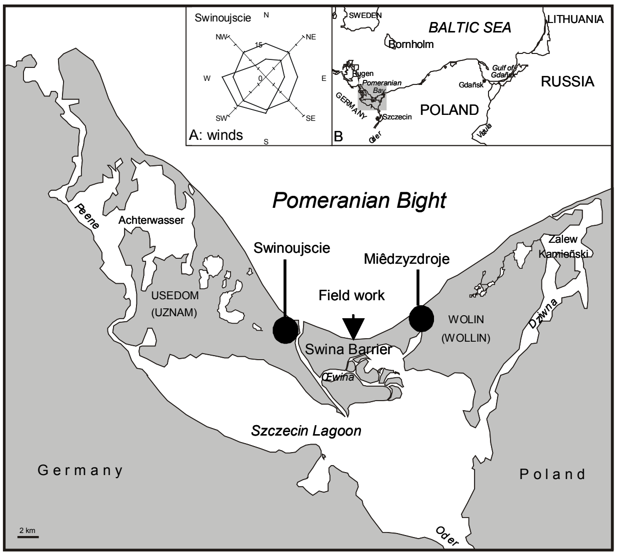
Today most of the Polish coastal and Baltic coastal habitats are threatened by human activities (Herbich, Warzocha 1999; von Nordheim et al. 1998). In order to analyse human impacts on dunal ecosystems it is necessary to first look at relatively undisturbed dunes like the remote middle part of the Świna Gate Barrier which is only accessible by foot (fig. 1). Accumulation of sand results in a prograding coastline (Keilhack 1912, Rosa 1963, Racinowski, Seul 1996) and an extensive dune ecosystem including the formation of new dune ridges (Łabuz 2002a, 2002b).

In future this coastline may also become more and more negatively affected by human activities (growing numbers of tourists in the region), as described for other parts of the southern Baltic coast (Piotrowska, Stasiak 1982, Isermann, Krisch 1995, Herbich, Warzocha 1999).

So far, research has focused mainly on the sand accumulation, and historic development of the coast (Keilhack 1912, Musielak 1995, Racinowki, Seul 1996). However, recent studies do not cover the youngest, still growing dunes. Work concentrated on the morphology (Osadczuk 2001) or vegetation of the older dunes (e.g. Bosiacka 2001, Piotrowska, Gos 1995). Only studies by Piotrowska and Celiński (e.g. 1965, 2002) included the vegetation of older and younger dunes.

2 Material and Methods

The study area is situated about 4 km west of Świnoujście and about 5 km east of Międzyzdroje (fig. 1). With limited public transportation and only few parking areas available, the beach along the middle section of the barrier is only visited by very few people and the impact from recreational activities is still minimal (Łabuz 2002b, 2003), whereas the beaches in Międzyzdroje as well as in Świnoujście are crowded popular holiday resorts.



A 20 m long section of the coastline was chosen for the study. The dune ridges (roman numbers) and depressions (capital letters) were labelled and three transects each about 10 m apart and two additional cross sections were laid, distances and elevations were measured. For all three profiles the vegetation and its range on the dunes was documented along a 2 m wide area. All trees, the larger shrubs and open sandy patches were marked as well (fig. 2).

Figure 1: Study area on Swina Gate Barrier (Wolin Island, A: Prevailing winds; B: Southern Baltic Sea region).

Vegetation was further documented along the western edge of the study area. 60 Plots of 2.5 m lengths were set up. Two plots for each different dune zone or vegetation type were made. The width of plots depended on the homogeneity of the vegetation and the extent of morphological forms in each section. The method described by Braun-Blanquet (Barkmann et al. 1964) was used and species (vascular plants, mosses) as well as their abundances were documented. "Zeigerwerte" or ecological indicator values (Ellenberg et al., 1992) of the different plots were calculated (fig. 5) for the parameters light (L), moisture (F), soil-acidity (R), and nitrogen (N); (Table 1).

3 Results

3.1 Morphology

Dune ridges and depressions

On the dunes 5 ridges and 5 depressions can be identified. Fig. 2 gives an overview of dune ridges and depressions showing elevation and extent of each feature as well as the development of the youngest dune along the three measured transects. The depressions between the ridges are generally less exposed to wind as well as sun. Whereas the older ridges I to III are similar grey dunes and differ mostly in width and height, ridge four (IV) is very narrow with steep slopes. It is an old white dune or a young grey dune showing the beginning accumulation of humus. This ridge was situated right at the beachfront in 1997 (Łabuz 2002b). The latest and youngest depression (E) is the widest and most heterogenic (fig. 2). It is divided into a flat deflation area and into an accumulation area with numerous hillocks (up to about 0.5 m high). The winter storms of 2001/02 abraded and partly cut first ridge. Organic material such as driftwood, dead plants or parts, seeds and garbage accumulated in the gutter. The land side slope of the youngest ridge (V) is very steep. The seaside slope (sometimes a small cliff) has signs of strong abrasion from winter storms (winter 2001/02). In some parts of the coast this youngest ridge was completely destroyed by winter storms. At the time of the study sand was already accumulating again and partly covering the dunal cliff.

Beach

On the Świna Gate barrier beaches are the widest (50-60 m, typical for an accumulation coast) of all Polish coasts. The beach may be divided at the drift line into a lower and an upper beach. The drift line represents the high water marks or swash marks of the latest winter storms and is characterized by a lot of organic debris (as well as garbage). Further up the beach primary dunes have started to develop where sand could accumulate around plants or other obstacles such as driftwood.

3.2 Vegetation

The vegetation and the morphology of the dunes are highly interdependent. Fig. 2 shows the range of selected species on the study area, table 1 gives a complete species list (vascular plants and some mosses) and fig. 4 and tab. 2 show the ecological indicator values. Plants characteristic for forested dunes slowly advance into the younger dunes. Their numbers decrease in second depression (B). *Pinus sylvestris* and *Salix daphnoides*, however, still cover more than ¾ of its surface. The most abundant grasses or herbs are *Deschampsia flexuosa, Polypodium vulgare*, and the *mosses Pleurozium schreberi, Dicranum polysetum, D. scoparium, Hypnum cupressiforme*.

The habitat under mature willows is characterized by a greater diversity within the herb layer than habitats under pine trees (in depression B on ridge II). Older grey dunes have the highest species richness (fig. 4) with higher species numbers generally inside the sheltered dune slacks A & B or the respective slopes.

On sandy sunny areas psammophilous plants adapted to high temperatures and stabilized sand reach their biggest density on and between the second and fourth ridge (fig. 2 + 3). Species like *Helichrysum arenarium, Jasione montana, Hieracium umbellatum, Festuca polesica, Corynephorus canescens, Sedum acre* and mosses like *Polytrichum piliferum* or *Ceratodon purpureus* are characteristic for grey non-forested dunes. Some sandy surfaces are only covered by a few *Corynephorus canescens* and some dying *Ammophila arenaria* indicating a secondary succession and an earlier naturally or anthropogenic disturbance (fig. 2).

Vascular Plants:	**Mosses:**
Achillea millefolium ssp. millefolium L.	*Aulacomnium androgynum* (HEDW.) SCHWAEGR.
Agropyron junceum (L.) P.B.	*Brachythecium albicans* (HEDW.) B.S.G.
Agropyron repens (L.) P.B.	*Brachythecium rutabulum* (HEDW.) B.S.G.
Ammophila arenaria L.	*Bryum argenteum* HEDW.
x Calammophila baltica (FLÜGGE ex SCHRADER) BRAND	*Cephaloziella spec.* (NEES) SCHIFFN.
Anthoxanthum odoratum L.	*Ceratodon purpureus* (HEDW.) BRID.
Anthyllis vulneraria L.*	*Dicranum polysetum* SW.
Artemisia campestris L.	*Dicranum scoparium* HEDW.
Betula pendula ROTH.	*Eurhynchium swartzii* (TÜR.) CURNOW
Cakile maritima ssp. baltica. (JORDAN EX ROY et FOUC.) HYL	*Hypnum cupressiforme s.str.* HEDW.
Calamagrostis epigejos (L.) ROTH	*Lophocolea bidentata* (L.) DUM.
Cardaminopsis arenosa ssp. *arenosa (L.) HAYEK*	*Lophocolea heterophylla* (SCHRAD.) DUM.
Carex arenaria L.	*Plagiomnium affine* (FUNCK) KOP.
Cerastium semidecandrum L.	*Pleurozium schreberi* (BRID.) MITT.
Chondrilla juncea L.	*Pohlia nutans* (HEDW.) LINDB.
Conyza canadensis (L.) CHRONQUIST	*Polytrichum juniperinum* HEDW.
Corynephorus canescens (L.) P. B.	*Polytrichum piliferum* SCHREB. EX HEDW.
Deschampsia flexuosa (L.) Trin.	*Ptilidium ciliare* (L.) HAMPE
Epipactis atrorubens (HOFFM. EX BERNH.) BESSER	*Rhacomitrium elongatum* FRISV.
Erigeron acris L.	*Scleropodium purum* (HEDW.) LIMPR.
Festuca polesica ZAPAL.	
Festuca rubra L. ssp. *rubra*	
Festuca rubra ssp.*arenaria (OSBECK) SYME*	
Galium verum L.	
Helichrysum arenarium (L.) MOENCH	
Hieracium lachenalii C.C. GMEL.	
Hieracium pilosella L.	
Hieracium umbellatum L.	
Honkenya peploides (L.) EHRH.	
Hypochaeris radicata L.	
Jasione montana L.	
Knautia arvensis (L.) COULTER	
Leymus arenarius (L.) HOCHST.	
Luzula campestris (L.) DC.	
Monotropa hypopitys agg.	
Moneses uniflora (L.) A. GRAY	
Orthilia secunda L.) House*	
Petasites spurius (RETZ) RCHB.	
Phragmites australis (CAV.) TRIN. EX STEUD.	
Pinus sylvestris L.	
Polypodium vulgare L.	
Pyrola minor L.	
Quercus robur L.	
Salix daphnoides VILL.	
Salsola kali L.	
Sedum acre L.	
Taraxacum spec.	
Trifolium arvense L.	
Vicia hirsuta (L.) S. F. GRAY	
(species marked with * occurred just outside the actual study area)	

Table 1: List of all vascular plants and mosses found inside the study area (or nearby).

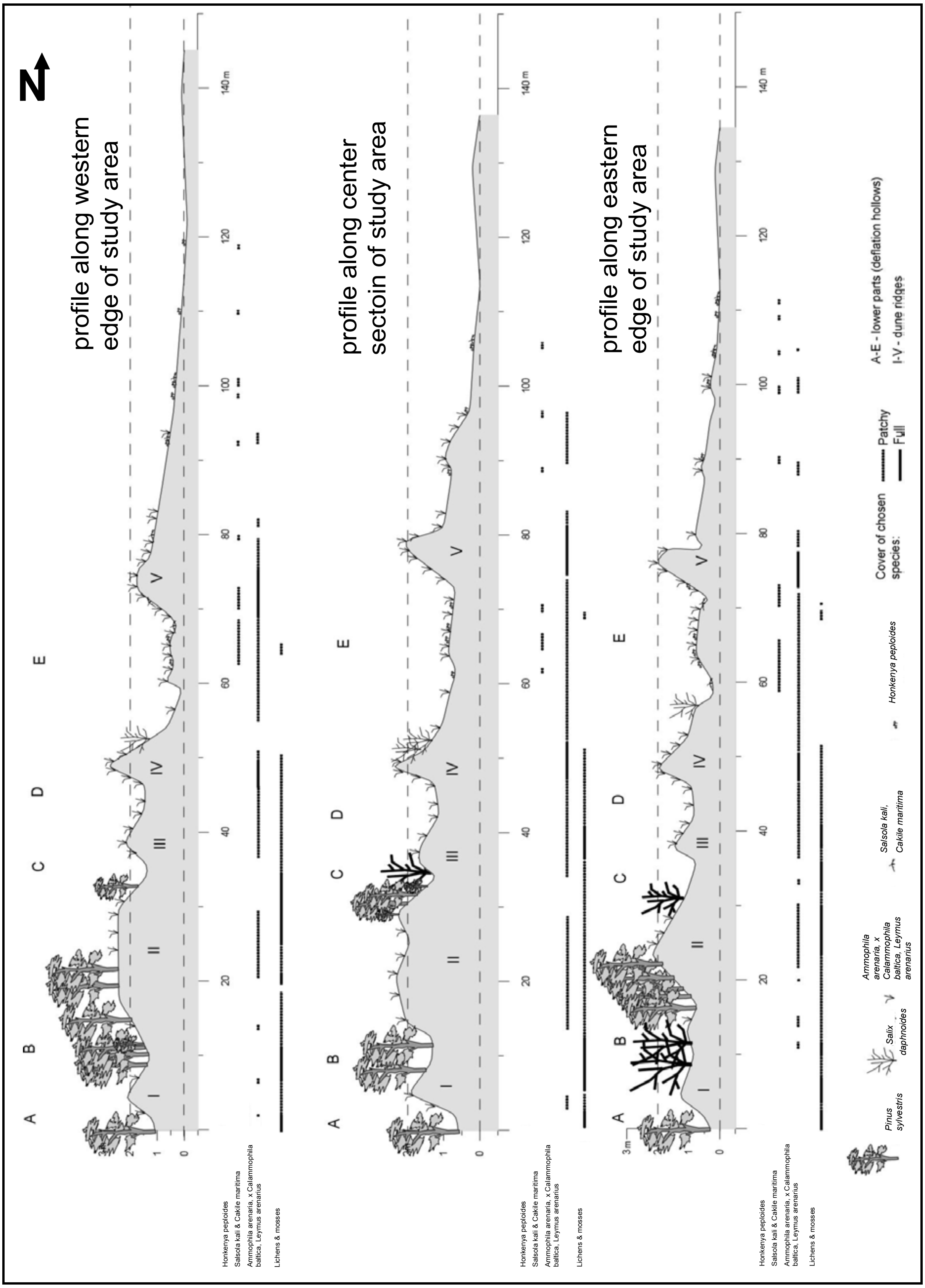


Figure 2: Three transects (south – north) with the distribution of selected plant species, typical for different dune zones (summer 2002).

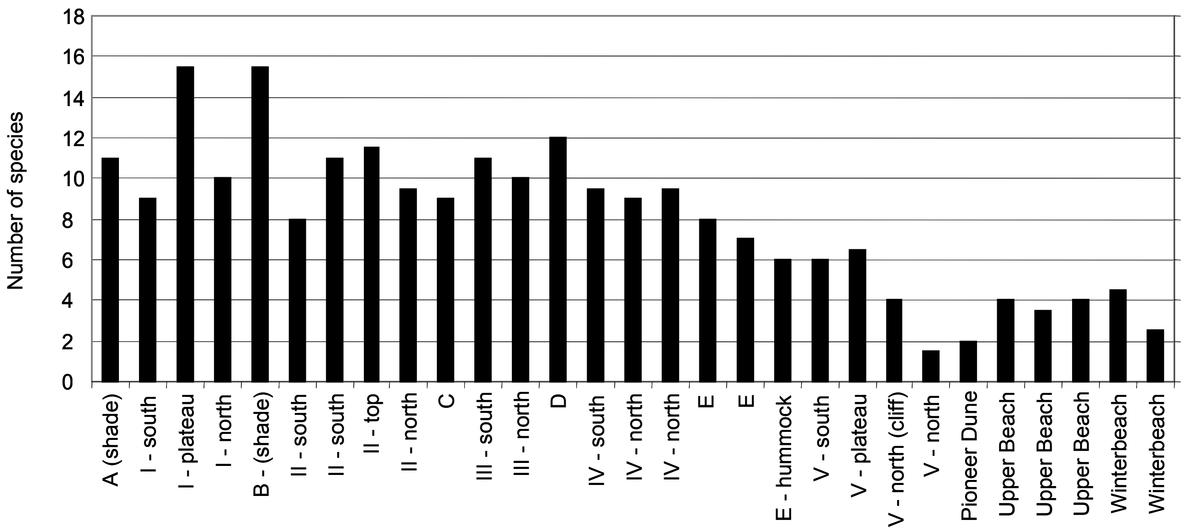


Figure 3: Number of species in the different beach and dune zones (always mean of two parallel plots).

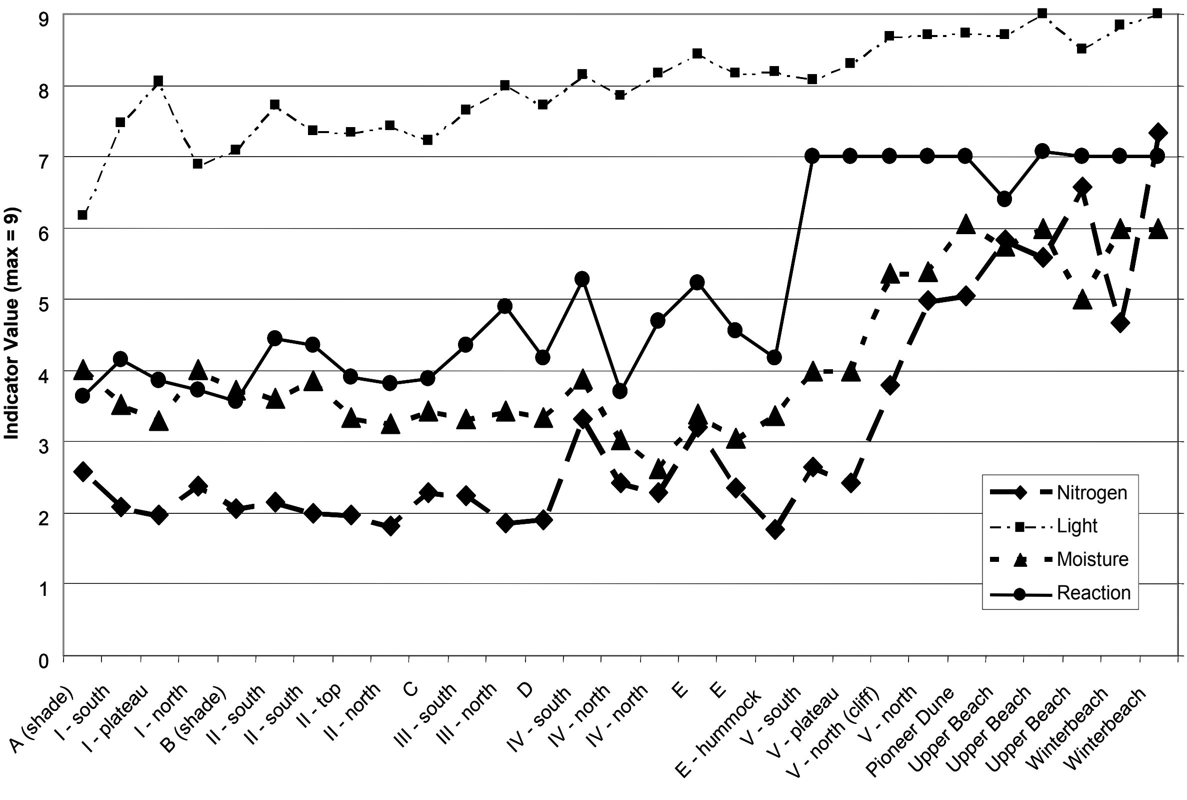


Figure 4: Ecological indicator values (mean of two transects) for vegetational plots on the central Swina Gate Barrier (mean of two parallel plots).

In dune slacks C and D as well as on the smaller ridge III the species numbers decrease and only few vascular plants have been able to establish themselves so far (fig. 3). Pinus sylvestris is just establishing itself in the narrow depression C. Lichens and mosses as well as some vascular plants typical for dry sandy habitats on older open dunes become less abundant. Behind fourth ridge towards the sea only few typical pioneer species are growing indicating the growing influence from moving sand. The hybrid x Calammophila baltica is more dominant than Ammophila arenaria or Leymus arenarius. Honkenya peploides, Salsola kali and Cakile maritima grows mostly on the upper beach.

Under …	tree cover	Num. of species	L (light)	T (temp.)	F (moisture)	R (acidity) low value = high accidity	N (nitrogen)
Salix daphnoides	approx. 45 %	14	5,63	4,32	4,36	3,74	2,48
Pinus sylvestris	approx. 19 %	12	6,9	4,75	3,48	2,97	1,17

Table 2: Ecological Indicator Values (Ellenberg et al. 1992) for herb layer (including mosses) in two typical dune habitats under trees (maximum value: 9, minimum: 0).

4 Discussion

On older stabilised ridges (I-III) and neighbouring depressions it is possible to identify at least four different habitats. Two habitats can be distinguished on the open sandy areas: One is characteristic for undisturbed areas with Festuca polesica, Carex arenaria, Helichrysum arenaria, Jasione montana mosses and lichens (e.g. Helichryso-Jasionetum) whereas the second one shows signs of natural or anthropogenic disturbance and secondary succession with a higher abundance of Corynephorus canescens and the appearance of Ammophila arenaria and x Calammophila baltica (e.g. Violo-Corynephoretum festucetosum) The third and fourth habitat types are associated with deciduous or coniferous trees (table 2). The habitat under Pinus sylvestris is much dryer, warmer and less shaded (indicator values F, T & L) than the one under willow shrubs and trees. The needles make up much of the organic litter, which decomposes much more slowly than litter from broadleaf trees and leads to a higher soil acidity (lower indicator value), but lower level of available nutrients (indicator values R & N). If the conditions are very dry only few grasses such as Festuca rubra, herbs like Cardaminopsis arenosa, Vicia hirsuta and some mosses and lichens will grow. If conditions are a little moister species like Polypodium vulgare, Dicranum scoparium (moss), Deschampsia flexuosa, Epipactis atrorubens will grow (especially on northern slopes). They are also common under willow trees, but here also Taraxacum spec., Trifolium arvense, Brachythecium rutabulum (moss), and others grow. The almost complete absence of Carex arenaria is surprising, since it otherwise common in the area as well as further to the west on Usnam (e.g. Isermann 1997).

Plants growing on younger more dynamic ridges are mostly psammophilous grasses whereas most other species (Honkenya peploides, Helichrysum arenarium, Corynephorus canescens, and Artemisia campestris) are mostly restricted to the depression. Some of them were washed away by winter flooding in 2001/02. During the study the remaining gutter was not densely covered by plants (some Corynephorus canescens seedlings). Some species, normally typical for the beach or fore dune communities, managed to germinate in this special pioneer habitat (Honkenya peploides). On the other hand plants typical for older dunes such as Helichrysum arenarium, Sedum acre, Hieracium umbellatum, and Epipactis atrorubens grow inside the depression on the small hillocks or next to young willow shrubs where they are sheltered from wind and sand burning.

Some pioneer species are flourishing where sand is still accumulating and providing nutrients needed by the plants (Ammophila arenaria, x Calammophila baltica). The indicator values R (acidity) and N (nitrogen) show the leaching of carbonates and nutrients from the sand along the transect (fig. 4) to the beach (high carbonate levels = low acidity) towards the older dunes (lower carbonate levels = high acidity). On older stabilised dunes these nutrients have been leached out and other plants, which can cope with the poor soils, but are less tolerant to being sand burial, move in and slowly replace the pioneer grasses. Plants from forest habitats are sensitive to direct and strong sun radiation and prefer the shade where conditions are generally a little cooler, moister and some accumulation of humus provide more nutrients. This is also reflected in the ecological indicator values for moisture (F) and light (L). The mean values (fig. 4) decrease moving from the beach onto the dunes and then F slowly tends to increase again on the older dunes, especially in the dune slacks near the forest.

Honkenya peploides plays an important role in sand accumulation (e.g. Reinke, 1920) and habitat creation for typical initial dune grasses like Agropyron junceum and Leymus arenarius characteristic for the Agropyro-Honkenyetum peploides and Elymo-Agropyretum communities. Cakile maritima, Salsola kali characterise the Cakiletum maritimae - a typical annual drift zone community (Piotrowska, Celiński 1965, Piotrowska, Gos 1995). Species from the genera Atriplex, Rumex or Chenopodium are very rare in the central part of the barrier, but quite common further to the west near Świnoujście. The annual drift zone communities are not well developed on this part of the barrier; which may be a result of more organic material being deposited along the western part of Wolin Island and more sand supply along the central parts of the barrier. The indicator values for moisture and nitrogen (F and N) show the highest values on the beach and a steep decline behind the youngest ridge (fig. 4).

After surveying mostly intact beach and dune ecosystem, it is now possible to look at disturbed sites, e.g. in the vicinity of holiday resorts. Here morphodynamics and vegetation are also changed by trampling and beach management (mechanical stress and eutrophication). On the other hand this little disturbed section of the coastline may itself become more and more negatively affected by tourist activities. Now changes and especially negative effects from recreational activities can be monitored and management measures can be taken.

References

Barkmann, J., J.H. Doing, S. Segal (1964): Kritische Bemerkungen und Vorschläge zur Quantitativen Vegetationsanalyse. Acta Bot. Neerlandica 13, Amsterdam, pp. 394-419.

Bosiacka, B. (2001): Zróżnicowanie i dynamika borów nadmorskich na zachodnim wybrzeżu Polski - Rozpr. dokt., 105 pp.

Ellenberg, H., H.E. Weber, R. Düll, V. Wirth, W. Werner & D. Paulißen (1992): Zeigerwerte von Pflanzen in Mitteleuropa. 2. and revised edition. Scripta Geobotanica XVIII. University of Göttingen. Göttingen 258 pp.

Herbich, J. & J. Warzocha (1999): Czerwona lista biotopów morskich i nadmorskich w polskiej strefie brzegowej. Ochrona Przyrody 56, pp. 2-16.

Isermann, M. & H. Krisch (1995): Dunes in Contradiction With Different Interests. An Example: The Camping-Ground Prerow (Darß/Baltic Sea) (in: Coastal Management and Habitat Conservation, Eds. A.H.P.M. Salman, H. Behrends & M. Bonazountas), European Union for Coastal Conservation (EUCC), Leiden, pp. 439-449.

Isermann, M. (1997): Vegetations- und standortskundliche Untersuchungen in Küstendünen Vorpommerns. PhD Thesis. University of Greifswald. 323pp.

Keilhack, K., (1912): Die Verlandung der Swinepforte. Jahrbuch der Königlich Preußischen Geolog., Land. Bd. XXXII, T. 2, Berlin, pp. 209-244.

Łabuz, T.A., (2002a): The beach vegetation cover as a indicator of dynamics on the Pommeranian Bay coast (in Polish). Czasopismo Geograficzne 73(3), pp. 245-256.

Łabuz, T.A., (2002b): Environmental importance of Honckenya peploides on the coast of Zatoka Pomorska (in Polish). Chrońmy Przyrodę Ojczystą 58(5), pp. 57-65.

Łabuz, T.A., (2003): Initial foredune field as a factor of accumulative character of coastal dunes of the Świna Gate Barrier (west Polish coast). Oceanological and Hydrobiological Studies, Vol. XXXII, Np.1, pp. 39-58.

Musielak, S. (1995): Shoreline dynamics between Niechorze and Świnoujście. In: Rotnicki, K. (ed.), Polish coast: past, present, future. Journal of Coastal Research, Special Issue 22, pp. 288-291.

v. Nordheim, H., D. Boedeker & R. Grunewald (1998): Evaluation of the red List of Bioitopes and Biotope Complexes of the Baltic Sea, Belt Sea and Kattegat. In: V. Nordheim & Boedeker, D. (eds.) 1998: Red List of Bioitopes and Biotope Complexes of the Baltic Sea, Belt Sea and Kattegat. Baltic Sea Environment Proceedings (Helcom) 1998. No. 75. 15 – 17.

Osadczuk, K. (2001): Geneza wałów piaszczystych Bramy Świny w świetle badań morfometrycznych i sedymentologicznych - Rozpr. dokt., Wydział Nauk Geograficznych i Geologicznych UAM, Poznań-Szczecin, 163 pp.

Piotrowska, H. (2002): Zbiorowiska psammofilne na wydmach polskiego brzegu Bałtyku. (Psammophilous habitats of the dunes of Polish Baltic sea coast). Acta Botanica Cassubica 3, 5-47.

Piotrowska, H., F. Celiński (1965): Zespoły psammofilne wysp Wolina i Południowo-wschodniego Uznamu. Badania Fizjograficzne Nad Polską Zachodnią, T. XVI, pp. 123-170.

Piotrowska, H. & J. Stasiak (1982): Naturalne i antropogeniczne zmiany strefowe flory naczyniowej bezleśnych wydm nadmorskich Mierzei Wiślanej. Fragmenta Floristica et Geobotanica, 28(3), pp. 372-396.

Piotrowska, H. & K. Gos (1995): Coastal dune vegetation in Poland. Diversity and development. In: van Dijk H. W. J. (ed.), Management and preservation of coastal habitats. Proc. of multidiscyplinary workshop in Jastrzębia Góra, Poland, 1-5.09.(1993, EUCC Leiden, Netherlands, pp. 71-82.

Racinowski, R. & C. Seul (1996): Actual morphodynamic attributes of Szczecin shore (in: Litodynamics of Seashore, Ed. Z. Meyer) - Polish Academy of Sciences, Technical University of Szczecin, Szczecin, pp. 107-116.

Reinke, J. (1920): Studien über die Dünen unserer Ostseeküste II. In: Wissenschaftliche Meeresuntersuchungen (Kommission zur wissenschaftlichen Untersuchung der deutschen Meere in Kiel und der Biologischen Anstalt auf Helgoland. Kiel & Leipzig.

Rosa, B. (1963): O rozwoju morfologicznym wybrzeża Polski w świetle dawnych form brzegowych - Studia Soc. Scient. Torunensis, Vol V, Toruń, 174 pp.

Address

Ralf Grunewald
Institute of Aquatic Ecology
University of Rostock
Albert-Einstein-Straße 3
18051 Rostock
Germany

E-mail: ralf.grunewald@biologie.uni-rostock.de

Thomas A. Łabuz
Laboratory of Marine Geomorphology
Institute of Marine Sciences
University of Szczecin
Felczaka str. 3a, 71-412 Szczecin
Poland

E-mail: labuztom@univ.szczecin.pl