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Title: Perspectives in coastal dune management : proceedings of the European symposium, Leiden, September 7-11, 1987, the Netherlands /
Article: Piotrowska, H: Natural and anthropogenic changes in sanddunes and their vegetation on the southern Baltic coast.
Date: 1989
Pages: 33-40 PleaseCopy
Imprint: Den Haag : SPB Academic Pub., 1989.
ISBN: 9789051030259

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NATURAL AND ANTHROPOGENIC CHANGES IN SAND-DUNES AND THEIR VEGETATION ON THE SOUTHERN BALTIC COAST

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Keywords: abrasion, dune protection, dune vegetation, Poland, recreation

Abstract

This paper deals with coastal dunes in Poland and its neighbouring countries. Features of the geomorphology, substratum, soils and vegetation are outlined. The temporal and spatial changes as a result of natural factors and of human activities, the assessment of protection methods and the impact of recreation and of coastal abrasion are presented.

Introduction

The southern shore of the Baltic Sea is relatively young: its evolution has progressed from the end of the Pleistocene through the Holocene down to the present day. Most of this coastline is now Polish territory, the remaining stretches being in East Germany and Lithuanian SSR (Fig. 1A). In Poland, coastal dunes make up about 80% of the length of the coastline, a combined distance of 400 km. Stretches of dunes alternate with cliffs (Fig. 1B). From the Oder to the Niemen, dunes have given rise to some 14 long sandbars, and in places they border on coastal lowlands or lie at the foot of stabilized cliffs. The width of the barriers varies from less than 100 m to about 3500 m (usually up to 1000 m), their length, from a few to 95 km. Moving eastwards, they get progressively longer. The coastal dunes are usually 3-8 m high, and rarely higher than 10 m. A feature of the mobile dunes, both stabilized and active, is their considerable relative and absolute height. On the Łeba Bar, maximum heights range from 40 to 56 m above mean sea level and on the Kuronska Bar from 40 to 70 m (Redman, 1938; Paul, 1944; Miszalski, 1973; Marsz, 1975).

Habitat conditions and natural vegetation

On this part of the Baltic coastline, taken over the year as a whole, on the average the prevailing winds are westerly. They are strong. The dune sand contains 95% quartz, is fine- and medium-grained, oligotrophic, non-calcareous and susceptible to acidification. On the beach and yellow dunes, the pH of the sand is 7, on the grey dunes it is weakly acidic, but in the forest soils it is strongly acidic. The principal soil-forming process is podzolization, which may lead to the formation of Baltic podzols or gley-podzolic soils. Mature forest soils are rare, but initial and intermediate stages are common (Piotrowska, 1960; Fukarek, 1961; Prusinkiewicz 1961, 1972; Wojterski, 1964; Dzięciołowski, 1975).

Perspectives in coastal dune management pp. 33–40
edited by F. van der Meulen, P.D. Jungerius and J.H. Visser

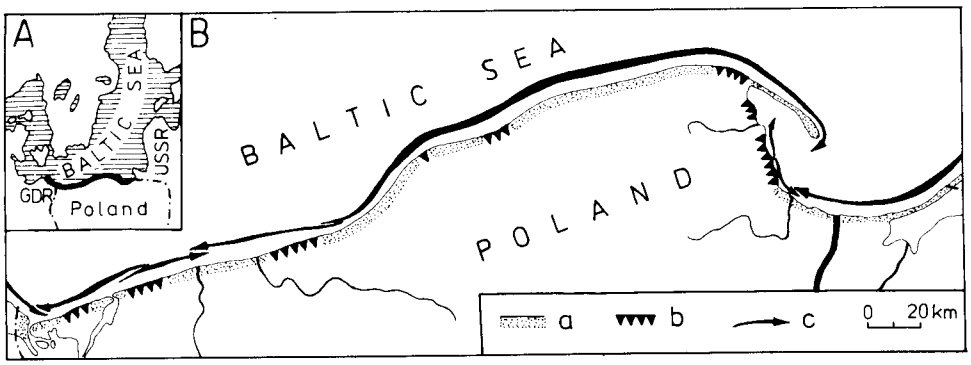

Fig. 1. Location of the dune vegetation on the south coast of the Baltic Sea (A) and in Poland (B). a) dune shore; b) cliffs; c) shore streams (based on Subotowicz 1977).

The low trophic conditions of the dune substratum, coupled with eolian processes, give rise to a low diversity in plant species and plant communities. The initial community on the yellow dunes is the *Elymo-Ammophiletum* (associations according to the Braun-Blanquet plant sociological system). The second stage in the succession, on the grey dunes, leads to a psammophilic sward (*Helichryso-Jasionetum*). The terminal stages are woodland communities: pine forest (*Empetro nigri-Pinetum*) on oligotrophic substrata, and mixed deciduous woodland (*Betulo-Quercetum*) on the mesotrophic substratum of the low dunes (Fig. 2). On active mobile dunes, the succession includes only two stages of psammophilic vegetation and never leads to woodland. The vegetation development in the moist deflation hollows (Fig. 3), left behind the moving dunes begins with psammophytes, after which heathland dominates. This succession is completed by pine forest (*Empetro-Pinetum*).

Historical changes in the dunes and their vegetation

Palynological examinations of fossil soils have shown that during the Subboreal period, the first woodland community on the sand-bars of the central and eastern parts of this coast were mesophilic oakwoods. The bars consisted of low rampart dunes lying parallel to the shoreline (Redman, 1938; Paul, 1944; Marsz, 1975; Tobolski, 1975a,b). On the Łeba Bar, these oakwoods began their expansion 3000-2800 years B.P. and in time covered the whole bar. But at about 2000 B.P. they were nearly all destroyed by fires. Their habitats were partially taken over by acidophilic beach woods, but these, from the Middle Ages onwards, were gradually felled. The decline of deciduous woodland in the area, due to human activities, led to intensified wind erosion and at the same time to the increased importance of pine (Tobolski, 1975a,b). From the 16th to the 18th centuries, huge moving dunes came into existence and began to migrate on the Łeba, Vistula and Kurońska Bars. They finally destroyed what remained of the forests. They brought about drastic changes in the relief and dry habitats expanded at the expense of moist ones (Redman, 1938; Paul, 1944; Piotrowska and Stasiak, 1982a).

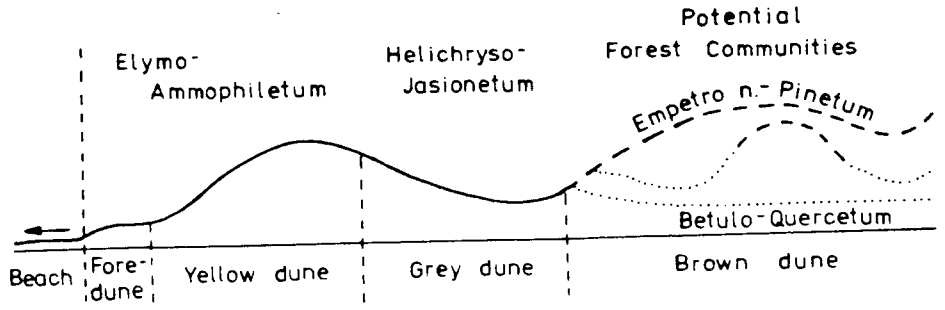

Fig. 2. The zonal distribution of communities on the Polish coastal dunes (simplified diagram).

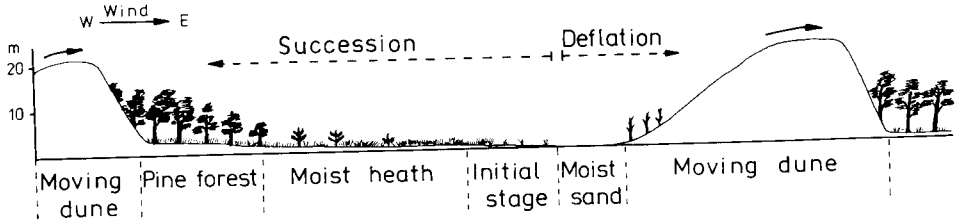

Fig. 3. The development and destruction of vegetation in deflation hollows (simplified diagram).

Stabilization of the dunes in the 19th century

Since the 17th and 18th centuries the mobile dunes threatened to overblow human settlements. Dune stabilization was begun at the start of the 19th century. Networks were thatched with reeds or brushwood, and psammophytes were planted. These measures were followed by pine nurseries planted on mulched sand. Conifer plantations were gradually introduced along the whole coast. On the seaward side, only the yellow dunes and a narrow strip of the grey dunes were left free of trees. These activities, which continued throughout the first half of the 20th century, produced close-canopy woodland almost along the entire coast. Only part of the Łeba Bar was never afforested and the moving dunes still migrate here. They are protected now in the Słowiński National Park, which is one of the world's biosphere reserves.

During the 19th century, a regular yellow rampart dune was constructed along the beach. Brushwood fencing, willow palings and psammophyte planting were employed to favour the accumulation of blown sand. Shrubs such as *Rosa rugosa*, *Salix daphnoides*, *Pinus mughus* were planted in places along the tree-free belt of the grey dune (Preuss, 1906; Redman, 1938; Paul, 1944; Piotrowska and Stasiak, 1982a,b). In 1873 the first 'hard' engineering works, suchs as groynes and sea walls were constructed (Cieślak and Subotowicz, 1986).

Present-day methods of dune protection

The protection of the coastal belt is the responsibility of the Harbour Boards. Bio-

technical methods are usually employed on a dune coast, with groynes being the chief hydraulic engineering method. In order to maintain and restore dunes, the following techniques are used nowadays:
1. Where the beach borders the yellow dune, low fences of fascine or brushwood, or paling fences of willow (usually *Salix daphnoides* and *S. viminalis*) are erected.
2. Yellow and grey dunes being eroded or threatened with erosion, and abrasion slopes, are covered with brushwood, sometimes in a network. Eroded spots are planted with *Ammophila arenaria*.
3. Shrubs such as *Rosa rugosa*, *Salix daphnoides*, and sometimes *Hippophae rhamnoides* and *Pinus mughus* are planted on relatively stable grey dunes. Both *Pinus* species are nowadays less frequently used as in the 19th century.
4. Since about 25 years, the forest boundary was moved seawards artificially, with pines (*Pinus sylvestris*) being planted even on the yellow dune or adjacent to the beach. The seedlings are primed with a clay humus mulch which considerably improves the effectiveness of the operation. These nurseries are surrounded with a few rows of *Pinus nigra*.
5. Part of the dune shore is protected by groynes.

An assessment of protection measures

The pine plantations of the 19th and 20th century, permanently stabilized most of the dune substratum. The area of forest increased very considerably at the expense of the open habitats. These became restricted to a narrow belt of yellow and grey dunes adjoining the beach. The renewed shift of the woodland boundary towards the sea is effective locally and to a limited extent only, since most pine seedlings perish as a result of wind and wave erosion. The building and widening of a yellow rampart dune by wind and man restricted the losses of land, and in some places even contributed to its growth. The large numbers of groynes built in the 20th century have not fulfilled expectations: the sandbanks at their seaward ends are disappearing, while to the leeward of them in particilar, large abrasion bays are formed, in the same way as near harbour walls (Konarski, 1978; Cieślak and Subotowicz, 1986).

The increasing variety and intensity of the threats to which the dunes have been subjected since 1950 have emphasized the inadequacy of the previous protection measures. The main threats are rapid growth of recreation during the last 30 years, and (as far as natural factors are concerned) an increased shore abrasion.

The impact of large-scale recreation

From spring to autumn, more and more beaches are overcrowded with holidaymakers. They destroy the foredunes with sparse vegetation, resulting in an increase of wind erosion of yellow and grey dunes. Tourists are also responsible for the serious trampling of the woodland undergrowth and for littering the areas with their rubbish. Notices which forbid walking on the dunes and ask people to go to beaches along marked paths are not respected by everyone. Except for the plantations of seedlings, which are fenced off, the older woodlands are generally accessible on foot. There is

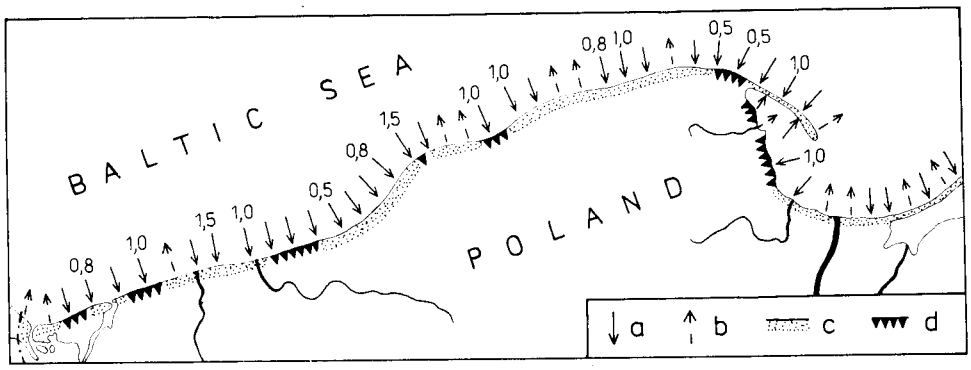

Fig. 4. Present-day dynamics of the Polish shoreline: a) abrasion -average in m/year; b) accumulation; c) dunes; d) cliffs (based on Cieślak and Subotowicz, 1986).

an increasing number of holiday places threatening woodlands. Numerous camp- and caravan sites completely destroy the woodland undergrowth and soil, and the network of 'wild' paths expands continually. These and other human activities destroyed many coastal woods and treeless dunes.

The impact of coastal abrasion

Accretion and abrasion of the shore are processes that have always shaped the Baltic dunes. The abrasion of Pleistocene uplands and the formation of sand-bars between them transforming former bays into coastal lakes, has evened out the shoreline of Poland and the Lithuanian SSR. Thus, the very intensive growth of dune areas came to an end. At the present time, only the East German coastline is still varied, where sections susceptible to abrasion alternate with areas of accumulation (Fukarek, 1961).

Archival data indicate that from the 18th century to the mid-20th, the shoreline of Poland has in many places receded by over 100 m (Konarski, 1978). In recent decades, abrasion is beginning to exceed accretion in intensity and on ever longer stretches of the shore. Abrasion of Pleistocene cliffs means the recession of Holocene dunes. Measurements made over many years have shown that the Polish shoreline is receding at an average rate of 1 m per year (Fig. 4), and in some places by several metres per year. The loss of land occurs irregularly in time and space, usually during autumn and winter storms. During the year there may be 2-5 severe storms, and once in many years, the effects of such a storm may be quite disastrous. The increased abrasion in the southern Baltic is explained by the gradual depression of the shore and rise of the sea level of 1 mm per year (Jelgersma, 1979). Along the Polish coastline, the quantity of material moved by the longshore current is decreasing year by year; offshore sand banks are being scoured away, beaches are getting narrower and the dunes lower and lower. Wave erosion of the dune shore is widespread, whereas sand accumulation is local and periodic. A fair amount of accretion is only at the very western end of the Polish coast (Konarski, 1978; Cieślak and Subotowicz, 1986).

The effects of the catastrophic storm of January 1983 are that along 75% of the

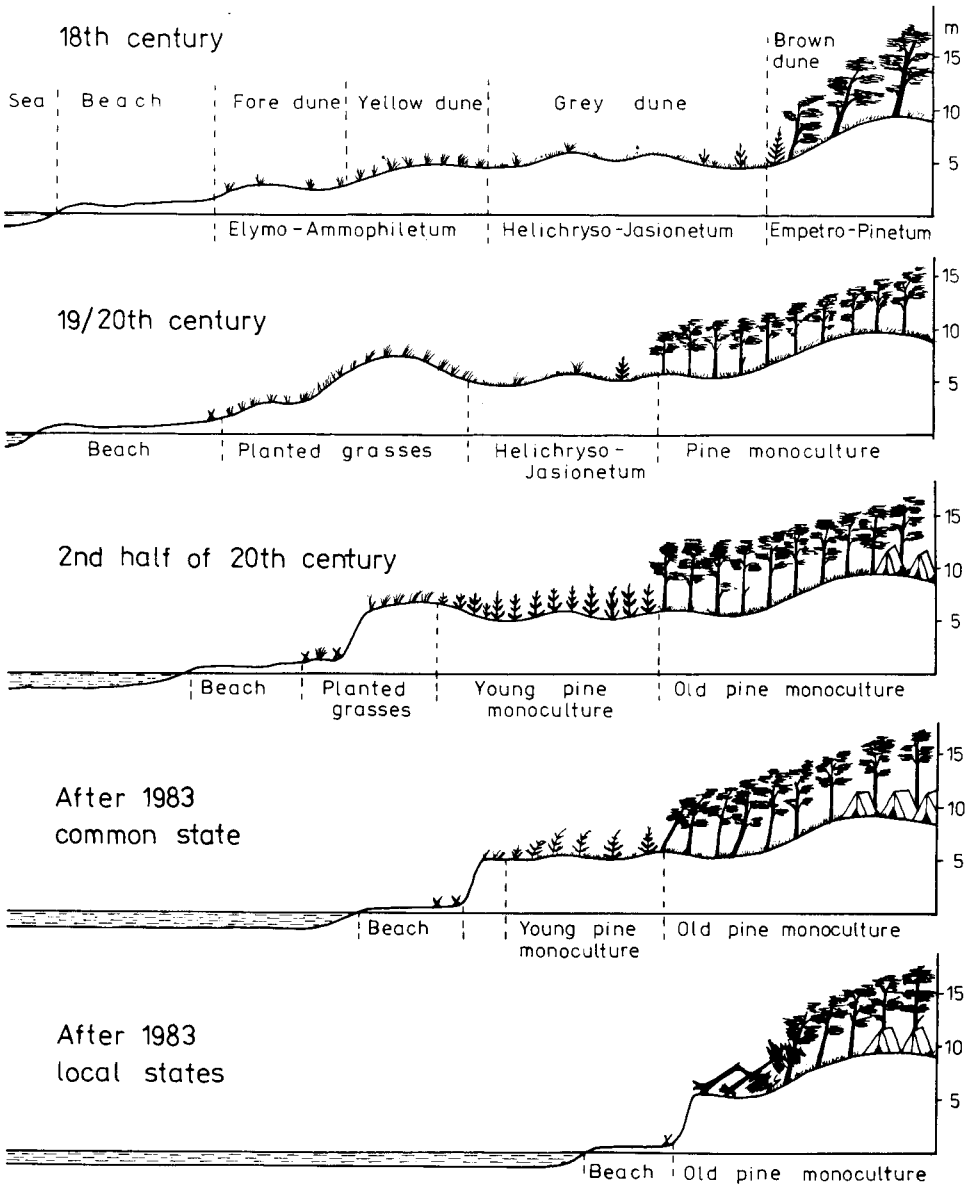

Fig. 5. The history of dune shore management and coastal abrasion (simplified diagram).

length of the Polish dune coast (ca. 300 km), the beach is not wider than 15-20 m, the yellow dunes are practically non-existent, the grey dunes are in a fragmented state and in places have gone altogether (Fig. 5). Locally, abrasion also destroyed woodland. Those woods that remained and now adjoin beaches are being blown down by the sea wind. The undergrowth is buried under blown sand and sometimes under sand washed there by the waves. Many sand-bars or parts of them became narrower; several

nearly 100 m. Some were breached by the storm waves. The low dunes at the foot of cliffs vanished completely.

The disaster of four years ago demonstrated the inadequacy of the dune protection measures so far undertaken and there is an urgent need for new solutions. On some stretches construction has begun of a rampart between the beach and low-lying woodland using bulldozers and local or imported sand. Beaches are still being nourished with sand dredged up from shipping lanes in ports. The abraded dune slopes, stretching for kilometres, are strengthened with criss-cross mats of sticks or with willow palings erected along the footslopes. But these are only half-measures, which offer no hope for the restoration of the destroyed dunes at sites where the beaches are not being supplied with fresh sand from the sea.

Conclusions

1. For nearly 2000 years, man has directly or indirectly affected the vegetation and the relief morphology of the Baltic dunes. With the passing of centuries, the kind of human impact has changed and intensified, reaching a maximum in the 20th century.
2. The results of dune stabilization and restoration depends to a large extent on the natural trends in shoreline evolution. Favouring natural sand accretion has turned out to be far easier than counteracting abrasion.
3. The biological protection of coastal dunes by natural or introduced vegetation affords positive results where there is accumulation or where the shore is relatively stable; where abrasion is intense and widespread, this kind of protection is insufficient and its effects short-lived.

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