

## **Morphodynamics of the central Swina Gate Barrier foredunes (Polish coast) since 1995: a case study**

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### **Abstract**

The fieldwork was carried out on the Świna Gate Barrier shore (Polish Baltic coast). The investigations were started after a strong storm surge, that washed out foredunes on the Polish coast in November 1995. Since 1996, a new dune ridge has been observed to be expanding on the still developing beach. Although affected by storm surges and wave action, the new ridge has been persistent. The beach has becoming increasingly wider each year, more and more plants colonising the new dune ridge.

Keywords: Foredune morphodynamics; Aeolian processes; Swina Gate Barrier (Poland).

### **Introduction**

The foredune is the first dune ridge behind the beach zone where sand continues to accumulate (*e.g.* Hesp, 1984; Carter *et al.*, 1990). During 1-2 years, the ridge may increase in height and grasses will stabilise it within the subsequent 5-8 years (Carter *et al.*, 1990). A developing coast and a progradating dune system of middle Świna Gate Sandbar is a rarely encountered phenomenon on the Baltic coast. The multi-year morphology changes on the investigated area show that particularly the middle part of spit on Wolin has tendencies for rapid dune development.

### **Study area and methods**

The study area is located on the islands of Wolin and Usedom on the Pomeranian Bay coast (Fig. 1). In Poland, the spit extends for c. 16km from the morainic plateau at Międzyzdroje (Wolin Island) to the state border in Świnoujście (Usedom Island). At present, the entire barrier is covered by dune ridges formed during different accumulation stages. The ridges differ in morphology, lithology, and trending to reveal the consecutive phases of spit accretion and development. The youngest dunes, termed the "white dunes", have been forming since the 17th century. The study area is affected primarily by westerly and southerly (S, SW, W) winds (as recorded over 1961-1995 in the town of Świnoujście), while the north-easterly winds are the heaviest. Prolonged wind action enhances material transport from beaches located west and east of the area

to its central part. The upper beach is built up mostly by medium and fine sand (35 and 60%, respectively). The material building the foredune ridge contains up to 85% of fine and very fine sand and not more than 15% of medium sand. In winter, the importance of medium sand in the foredune increases (to 30-40%) in winter. Plant species typical sand accumulation on young dunes or dune fields include the psammophilous *Ammophila arenaria*, *Calamophila baltica* and *Elymus arenarius* and the halophilous *Honckenia peploides*. Other plants are characteristic of older fixed dunes.

The study involved measuring (i) dune relief changes, (ii) vegetation dynamics, (iii) human or animal influences, (iv) storm surges impact, and (v) wind impact. The measurements were taken several times during the year, particularly – and whenever possible – after every major manifestation of factors impacting the dunes. Relief changes were measured with geodesic devices from fixed plots (5x5m) along transects (1km apart, in various areas). Other measurements provided comprehensive information on the dynamics of the entire environment, e.g.: sand grain size, wind fields, vegetation dynamics or storm surges. The study is a part of the author's project focusing on the entire belt coastal dunes in Poland called ANDDY (Anthropogenic-Natural Dunes Dynamics; web pages: [bramaswiny.szc.pl](http://bramaswiny.szc.pl) and [polishdunes.szc.pl](http://polishdunes.szc.pl)). The aim of the paper is to describe the development of the central part of the Świna Gate Barrier (Polish coastline kilometre 420-421; Fig. 1).

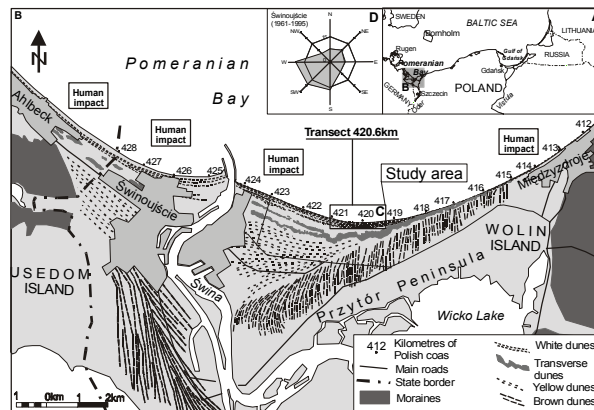


Fig. 1. Location of the Swina Gate Barrier (B) on the Southern Baltic (A); study area (C); wind rose (D).

## Foredune morphodynamics

In 1995, the upper beach of the area between 420-421km, up to 30m from the foredune, featured numerous small, 0.1 to 0.5m high, aeolian forms and was vegetated by pioneer plants. Hillocks on the beach were separated from each other by deflation depressions, the blow-outs, with organic material accumulated on their bottoms. The mean width of the beach was about 60-90m. The seaward slope of the foredune, i.e. the dune ridge closest to the beach and not yet stabilised, was abraded. The foredune measured up to 4m in height. In late autumn 1995, a very strong storm (surging to 1.5m above ASL) destroyed the beach's dense hillocks and plant habitats. It also cut the foredune off and/or washed it away in many places. In late spring 1996, however, the upper beach was again covered by numerous small aeolian forms. Locally, the foredune still showed an abraded seaward slope, but storm gaps were in many places filled up by the accumulated sand. Rather low (up to 0.2m) sandy "tongues" were seen on the foredune top. As of 1997, the hillocks were growing in size (Fig. 2). In some places they

connected with the foredune slope and looked like long, grass-fixed tongues running across the ridge and the water line. The increasingly denser grasses entrapped progressively higher amounts of sand. The highest hillocks and grasses posed major obstacles to the aeolian transport. Consequently, sand accumulation on the foredune was clearly diminishing, whereby the ridge was slowly becoming stabilised (by other plants). As a result of aeolian accumulation, the abraded seaward slope of the dune became initially transformed into a gently-shaped form. Between the ridge and a new one that was growing a deflation depression – a blow-out – appeared. Between 1998 and 2000, the narrow depressions between the hillocks were filled up by the sand. The embryo dunes became linked into a single dune ridge, parallel to the old one. The landward slope of that ridge was steep, the seaward one being flat. The new foredune did not have any straight ridge. It was a single ridge consisting of joined-together tops of the embryo dunes. Ridges of the embryo dunes run transverse to the new foredune ridge. The ridge described reached up to 2m. In front of it accumulation process and plant succession started again. In autumn and winter 2001, a few heavy storms (water level to 1.5m above ASL) damaged the dunes, with several storm gaps appearing in the foredune ridge of the studied area. The gaps, wider than 20m, allowed sea water incursions to the low-lying ground behind the foredune. No storms affected the area in winter 2002. It was only the ice cover of the beach that stopped sand transport from the lower beach in the direction of the foredune direction. In spring 2002, the sand accumulation process started filling all the gaps and gates in the foredune. The next cold season proceeded without storms; the accumulation was very small (0.1-0.2m), even on fixed dunes. In spring 2003, the foredune was up to 3m high. The low-lying part behind it became stabilised. During the growing season, a slow colonisation by mosses and lichens was observed. The sand was transported only through the storm gates where an active surface was visible. In autumn 2003, the foredune ridge was damaged by a single storm surge (with water reaching 1.5m above the ASL) and the entire upper beach was levelled off. The dune hillocks (up to 0.6m high) were cut off and the deflation depressions were filled with sand; the beach, however, was still c 70-90m wide. The heavy wind during the storm in question produced aeolian accumulation on the surfaces behind the foredune, fixed previously by mosses. In early spring, the sand, blown over the foredune from places that had not been ice-covered, accumulated on it, producing an 0.4m thick layer; the sand accumulated also in the previously stabilised depression between the first two dunes. In spring, the foredune was 4m (ASL) high and completely covered by grasses. Until summer 2004, the upper beach was covered by numerous hillocks 0.3-0.7m high. They were covered by grasses growing at a density comparable to that observed in 1997.

## Conclusions

The foredune in the central part of the barrier is not sufficiently stabilised by grasses and wide enough to withstand heavy storms. The foredune has been rising for the last 9 years. The former foredune had emerged in the area between 1986 and 1995; its formation took 9 years as well. Last autumn (2004), the foredune began to be colonised by plants that, as opposed to those that had been establishing themselves before, were not tolerant of sand fill-up.

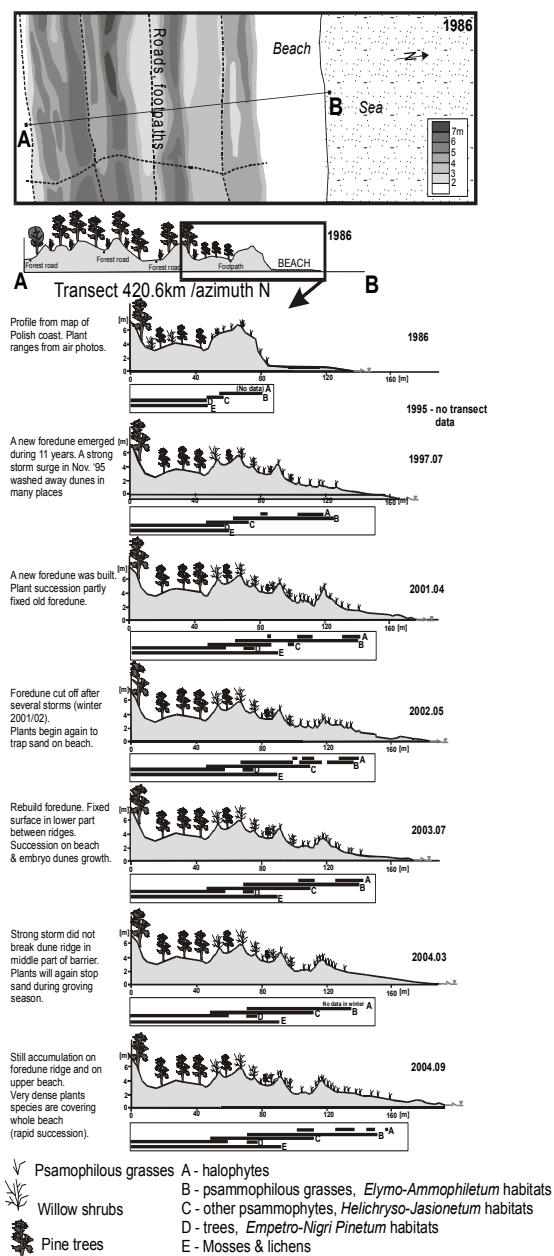


Fig. 2. Foredune morphodynamics with habitat changes in the central part of the Swina Gate Barrier: an example transect at km 420.6 off the Polish coast.

The new initial field of the foredune (third since 1986) was 30-40m wide, consisting of dune hillocks (shadow and embryo dunes) up to 1m high, densely vegetated by grasses. New dunes in the area do not develop at an identical rate; instead, the rate varies due to the wind and storm events. The winter season in the area may feature numerous storms one year (as in winters of 1995/6, 2001/2 or 2003/4) to be devoid of them next year. The same is true with respect to the wind regime. As a result of all the factors, new dunes emerge and will probably do so in the future. Storm surges are causing abrasion of the dunes but supply the beach with material. Low thickness of sand helps in aeolian transportation along barrier beaches. Absence of mass tourism leads to natural dune development in the middle part of the investigated barrier.

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