5.14 Dunes

R. Neuhaus
J. Petersen

5.14.1 Introduction

In the Wadden Sea Area, dunes can be found on the majority of the barrier islands and, to a small extent, on the mainland. Irrespective of the islands' or mainland's geological history, dunes develop as a result of landward sand transport arising from eroding glacial deposits in the North Sea basin and subsequent sorting by currents.

The location of the barrier dune-islands roughly reflects the shape of the mainland coast at a certain distance (compare Figure 1.2). The dunes themselves form a belt exposed to the North Sea which is prolonged to the North and the South along the Dutch and Danish mainlands in areas of lower tidal amplitude.

The West and East Frisian islands have mainly grown longitudinally in contrast to the North Frisian and Danish islands, which have grown latitudinally during the last transgressions. This general scheme, however, may have to be modified today because several islands have been partly fixed by coastal protection works.

Especially plant communities shape the outlook of several dune generations reaching from the beach into the hinterland thus forming classic examples of successional series, *i.e.* a principal developing sequence of communities in a given environment and/or gradient. Animal communities partly follow these series, whereas natural and anthropogenic disturbance often modify them by cutting one or more successional stages.

5.14.2 Vegetation

In addition to geomorphological descriptions, inventories of animal- and, especially, plant-communities prove to be valuable for a subsequent assessment of the dunes' status.

In spite of the fact that many of today's dune landscapes look natural, their former land use or actual management status should be considered to explain actual vegetation patterns.

The classical approach demonstrates communities arranged in series (*e.g.* Ranwell, 1972; Chapman, 1976; Pott, 1995) mostly as a result of succession, starting with *Elymus farctus* (*Elymo-Agropyretum*) which builds up the first small dunes on the shoreline. Soon, *Ammophila arenaria* (*Elymo-Ammophiletum*) invades into desalinating soil and builds up high white dunes carrying additional pioneer communities. Soil development (*e.g.* the accumulation of humus, decalcification, leaching of nutrients and acidification) accompanies the subsequent formation of grey dunes with a greater species richness in various characteristic plant species/communities like *Phleum arenarium* (*Tortulo-Phleetum*), *Galium verum* (*Festuco-Galietum*) and *Corynephorus canescens* (*Violo-Corynephoretum*). But also bushes, such as *Hippophae rhamnoides*, *Sambucus nigra* and *Salix repens* already invade. Grazing of rabbits and hare starts to have a considerable impact here. This intermediate stage is succeeded by the invasion of species like *Empetrum nigrum*, *Calluna vulgaris* and *Polypodium vulgare* (*Hieracio Empetretum*). As a result of further accumulation of humus or peat, the soils of these brown dunes show lowest pH-values. The species richness of plant communities of the brown dunes is lower than that of the grey dunes. Dwarf shrub heaths represent one possible final successional stage. Forest climax stages of *Betula pubescens*, *Populus tremula* and *Quercus robur* developed on the islands since the last century, when grazing, chopping of wood and turf cutting were ceased. Additionally, coastal protection measures stabilized a large proportion of the dune's surfaces by planting or by building of dikes, after which tree invasion occurred.

Succession in primary and secondary wet dune valleys usually starts with species-poor pioneer communities but soon species-rich communities develop.

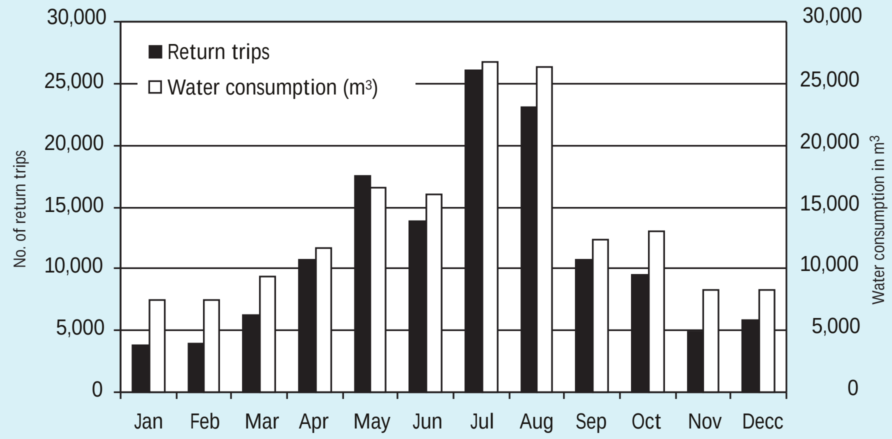
Rich fen vegetation depending on the presence of calcium in the soil or groundwater with *Schoenus nigricans* (*Junco baltici - Schoenteum nigricantis*) follows in the successional series. These communities as well as natural woodlands are considered to encompass today's rare species/communities. With the accumulation of humus and subsequent acidification, which may be due to low geomorphological dynamics, wet heaths with *Erica tetralix* (Empetro-Ericetum) or poor fens with *Carex nigra* (*Caricetum trinervi-nigrae*) appear. Wet heaths and forests are considered to represent analogous terminal stages in the wet successional (hygro-) series compared to the dry (xero-) series. Grazing and turf cutting during the last centuries have led to an enrichment of early successional stages instead of forests. After the cessation of such land use in The Netherlands, the woodland area has increased in size (Petersen, 1999).

5.14.3 Human impact

Farming

The suitability of dunes for agricultural use is limited. Only cranberry (*Vaccinium macrocarpum*) has been planted and harvested in The Netherlands. Grazing and mowing were practiced mainly in the

Figure 5.15. Annual course of groundwater consumption and return travels on the island of Vlieland (1994). Data kindly provided by Doeksen and Waterleiding Friesland.



dune valleys during the last centuries and are only carried out to a minor extent today. Many plant species were used for hay making and fuel (also cutting of soil turfs covered with heather (*Erica tetralix*). Low intensity use generated sites with communities similar to the pioneer communities and prevented the establishment of forests.

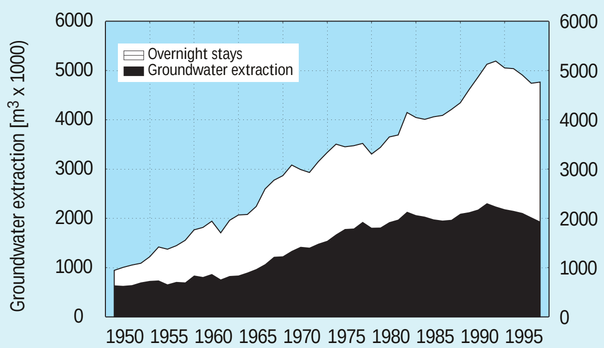
Tourism and recreation

Tourism and recreation started during the last, and gained importance, in this century. Human impact on the dunes is either direct by trampling and the subsequent destruction of vegetation or indirect by groundwater extraction as a consequence of increasing numbers of tourists. Overnight stays on almost all island villages have increased greatly from the fifties onwards (Rat von Sachverständigen, 1980) (see also 2.4).

It can, however, only in part, be proven directly that increasing numbers of tourists have, through increased consumption of drinking water, caused increased groundwater extraction which in turn has led to desiccation of dune areas.

Figure 5.15 shows a clear relationship between tourism and water consumption on the Dutch island of Vlieland for the year 1994 (Rus *et al.*, 1997).

Figure 5.16. Time course of the groundwater consumption (m^3) and overnight stays on Westerland/Sylt.



Groundwater consumption had increased from some 20,000 m^3 in 1955 to almost 180,000 m^3 in 1994. Several measures have been initiated in recent years to reduce ground water extraction, such as reduction of evaporation by forests, reduction of run-off from groundwater systems and water saving (Rus et al., 1997). Figure 5.16 shows a significant correlation between ground water consumption and overnight stays for the town of Westerland on the island of Sylt (Pearson correlation coefficient $r = 0.91$). Such a correlation could, however, not be established for the villages of Kampen, Wenningstedt, List and Hörnum on the same island. We can, thus, hold that there is evidence for a positive relationship between ground water consumption and the number of tourists on the Wadden Sea islands but that, in order to give a clearer perspective, a more comprehensive database must be analyzed.

Negative effects of ground water consumption on the water table may eventually lead to reactions of the plant and animal communities of the wet dune valleys. A principal reaction has been demonstrated by Raabe (1964) who documented that water use by *Pinus* plantations on Amrum lead to desiccation of wet dune valleys and a complete shift in community composition. This could be confirmed and refined by various authors from The Netherlands (see Sival, 1997). Especially Grootjans *et al.* (1991) found subtle effects. A shift in community composition with a decline in rare species resulted from ground water extraction, which led to a change in groundwater quality, *i.e.* a decalcification

Finally Nachtigall (unpublished, 1991) reported that he could not show a negative effect resulting from the extraction of 45, 000 m^3 groundwater per year in Rantum/Sylt, although this equals up to 25% of the annual consumption of the villages of List or Hörnum on the same island.

Coastal protection

Coastal protection can be characterized in terms of soft and hard measures. Soft measures, such as seeding and planting of dunes, arose during this century. The catchment of blown sand by plants like *Ammophila arenaria* was first documented by Dieren (1932) and led to extensive dune stabilizing measures in all countries; the building of sand dikes included. During the last decades, large amounts of sand were pumped from the sea floor to sites of major erosional damage both for sand dike building and shore nutrition.

Hard measures, often practiced when villages are directly endangered, include building of groynes, the use of concrete-tetrapods, asphalt-dikes or brickwalls to prevent further erosion. These constructions are irregularly scattered over the islands and can mostly be found in the uppermost littoral zone but also onshore.

The classical approach to stabilizing the coastline of the Wadden Sea islands means fixing the dunes in their positions via catchment of blown sand by planting and seeding *e.g. Ammophila arenaria* or erecting brushwood fences. This has caused a reduction of the area of partly mobile white dunes which can, therefore, be used as an indicator of either dynamic or conservative dune management.

Figure 5.17 demonstrates that the proportion of white dunes of the total dune area on Wadden Sea islands is quite different. A majority of eleven islands exhibit a share of 10 to 30% white dunes (mean = 20.5%; Rottumerplaat and Rottumeroog as developing, respectively, eroding high sands not included). Moreover, Figure 5.17 indicates the positive effect of dynamic management on Vlieland, Terschelling and Schiermonnikoog in The Netherlands and on Baltrum, Mellum and Amrum in Germany.

However, the proportion of white dunes does not exceed a threshold of 40-50 % which appears as an upper limit. A positive, linear relationship of total dune area to island size (r=0.83, not demonstrated here) indicates that island growth is influenced to a greater extent by sand nutrition with subseqent dune growth than via clay nutrition and the growth of salt marshes. The area of white dunes does not increase consistently for all islands considered here. In this context, the data set of Figure 5.17 has been split at the median value of 20% white dunes into two groups of islands with more (group A) or fewer (group B) white dunes and, hence, a more or less dynamic dune geomorphology. Correlation coefficients for both groups are highly significant with r=0.99 for islands with more than 20% white dunes and r=0.93 for islands with less than 20% white dunes and give a much better fit in the regression (Figure 5.18) than the combined calculation for both groups (r = 0.63). Group A (see Figure 5.18) consists almost entirely of the Dutch islands with Baltrum, Mellum and Amrum as German excep-

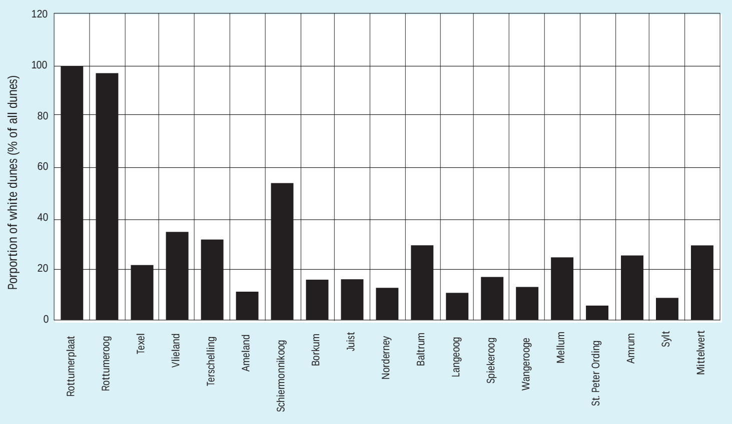


Figure 5.17. Percentage of white dunes of total dune area.

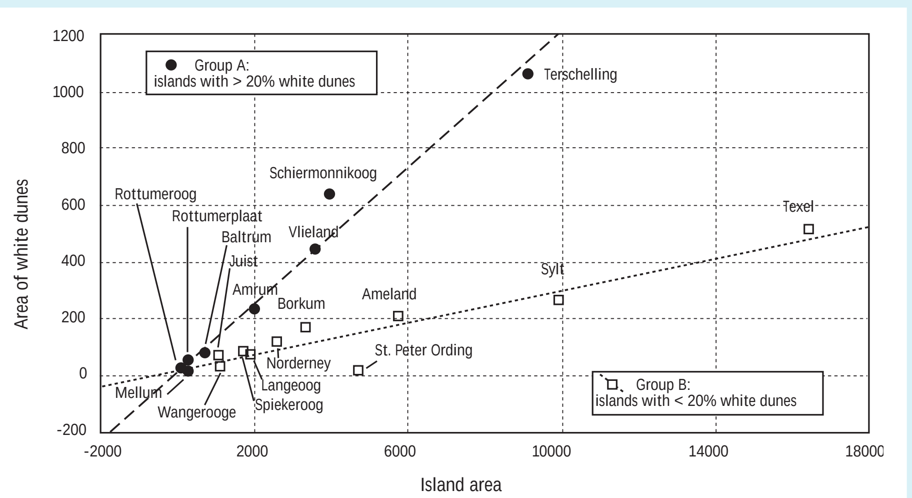


Figure 5.18. Regressions of islands areas on their white dune areas split into two groups.

tions. Group B only shows Texel and Ameland as Dutch exceptions in a German majority.

The reasons for higher or lower proportions of white dunes may be manifold. The specific hydrological and geomorphological conditions on the different islands should, however, be taken into consideration in such an assessment. It concerns, in particular, factors such as tidal range, exposure to storms, relative size of the dune area and erosion-sedimentation patterns.

Within these boundary conditions, the management practice of additional sand suppletion in The Netherlands, resulting in a higher dynamics of dunes, is considered an important reason for the observed differences. Of course, the evaluation of management cannot be done on the basis of white dunes as indicators alone. A discussion of all relevant cases and reasons will be necessary, which is, however, beyond the scope of this report.

Introduction of species

Besides the planting of marram grass, the planting of *Pinus* sp., *Quercus* sp., *Betula* sp. and other tree species strongly changed the dune landscape. The mostly even-aged plantations also affect the groundwater level to the detriment of wet dune valley communities (see above). Neophytes like *Rosa rugosa,* originally introduced on purpose, and a moss species, *Campylopus introflexus,* are expected to spread in future. Both species do not integrate in local plant communities but superimpose on them by forming monocultures.

5.14.4 Sea level rise

Besides human use or the direct action of wind and water, sea level rise is regarded as a principal driving force in keeping up a certain dynamics of the dunes on the Wadden Sea islands. Different speeds are responsible for higher or lower erosion activity at the coastline. To judge whether the situation today is more stable or unstable, a comparison with the sea level rise during the period of strong sand drift in the 14th to the16th centuries is required.

5.14.5 Conclusions

Coastal protection and tourism have influenced the dune landscapes of the Wadden Sea strongly and still do so. Agriculture, especially grazing as a former land use of the dunes, has lost direct influence. Indirect effects from drainage and eutrophication, however, are still likely to influence plant and animal communities negatively.

Conservative measures of coastal protection preserve directly (planting of marram grass) or indirectly (building of sand dikes, groynes *etc.*) the zoning patterns of today.

An intensified geomorphological dune turnover will improve community patterns to the benefit of complete series without emphasis on intermediate stages. Older dune areas (forests included) should develop by allowing some erosion, as this should be regarded as natural.

Natural dynamics, favored by many authorities today, in principle, includes rise, stagnation and regression of the sea level. It will be crucial to assess the magnitude of dune dynamics in terms of separate geomorphological driving forces as well as Man's share in these dynamics. One can expect a higher proportion of pioneer communities under the regime of a rising sea level and a higher proportion of woodlands or other climax communities in a stagnant period or in a regression due to a faster or slower turnover in the erosion/accretion regime. Thus the nature of rarity (of dune types, communities, species) is, when left in the hands of natural dynamics, dynamic itself and species *etc.* may go extinct locally but not in the whole variety of dune sites.

Intervention in terms of management should, therefore, be restricted and only applied when anthropogenic influences must be balanced.

Adding up a relatively low sea level rise and preserving measures in coastal protection, we find an imbalance here on the cost of early successional stages partly caused by Man. As long as this imbalance predominates and some plant communities are essentially endangered, a few dune valleys can still be managed and their vegetation, similar to that of early pioneer stages, can function as a 'species reservoir'. Giving way to erosion of older dune areas and increasing the turnover of dune formation, the chance for the establishment of such stages will increase and management regulations can be abandoned consequently.

The direct negative effects of tourism can be minimized more easily via consequent separation of intensively from extensively or unused areas. One indirect effect of tourism, groundwater extraction, is expected to be present on numerous islands and can be traced more clearly if the access to detailed data is made possible.

The spreading of alien/introduced species has to be monitored in order to detect signs of strong displacement effects on the local flora and fauna. In this context, the suppression of *Pinus* spp. may be forced, as this species acts as a main competitor for authochtonous woodland species.