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Thematic Report No. 15

Beaches and Dunes

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1. Introduction

Dunes on Norderney
(Photo: Norbert Hecker)

Nowadays more and more attention is paid to the actual state of large nature areas along the Northwest European coastlines. In recent publications on expected sea level rise, beach plains, dunes and salt marshes are considered as elementary constituents of the coastal defense structures. The corresponding ecosystems are also subject to the implementation of Natura 2000 in compliance with European nature policy. They are considered to be of major importance because they hold such a large proportion of the total diversity of habitats and species that must be protected on the European level.

1.1 Protection and Management

Beaches and dunes in the Wadden Sea area are almost exclusively situated on the North Sea side of the barrier islands. Generally speaking, the adjacent landforms of Wadden dunes have a more or less natural character. This applies not only to the bordering beach plains and foreshores but also to the areas adjacent to the inner dune fringes on the islands. These often consist of brackish grassland or high salt marshes transcending to lower salt marshes and (sub)littoral mud flats. However, small island villages are mostly located in the inner dune fringe as well. These are protected against flooding by the dunes on the North Sea side and by artificial dikes on the Wadden Sea side. On the Dutch islands, sometimes complete former salt marshes are included within these dikes. Water management in these "polders" may even be regulated by pumping stations and the salt marshes are transformed into productive grasslands. On the German and Danish islands, only relatively small parts of these salt marshes are diked and reclaimed and they are used in a more extensive way.

On the North Sea side, there are some dune areas which are heavily protected by all kinds of hard core structures, *e.g.* bordering the largest villages on Borkum and Norderney. On the other hand there are dune areas which are not "protected" at all. Blowing sand and overwash under stormy conditions are the primary forming, *i.e.* building and demolishing, factors on those sites. Additionally, there are large stretches of the coastline, especially along the Dutch islands where 'soft' protection by sand dikes dominates the transition zone between dunes and North Sea beaches. The effects of these structures are comparable to those of harder structures in the sense that they completely restrict dynamic processes on a landscape level. On the habitat level, the recent abandonment of regular maintenance of the sand dikes affects local dynamics by sand blowing directly in or from those dikes. This abandonment, at least where no buildings or crucial human interests are present immediately behind the dikes, is part of the change of sea defense management policy. At the same time, a systematic management system of sand nourishment on beaches or foreshores was introduced, where a retreat of the coastline occurs or is expected. The consequence of this is that the coastal erosion that characterizes the natural dynamics of the Wadden Sea islands is reduced or eliminated.

Despite the presence of all kind of restrictions, it may be concluded that the adjacent landforms of Wadden dunes have a far more natural character than those of the mainland dunes along the Northwest European coast. In The Netherlands and Belgium for example, the mainland dunes are strongly squeezed between towns, buildings and infrastructure at the inland side and the very severe coastal defense requirements at the seaside. The Wadden dunes, by contrast, are to a large extent embedded in very dominant natural landscapes of the North Sea as well as of the Wadden Sea. This characteristic position gives many more opportunities to counteract the negative effects of sea level rise by adapting management to complement the natural processes which are involved. Also, the protection and restoration of priority habitats and species in Natura 2000 may be very well served by placing more emphasis on the role of natural processes on different spatial and temporal scales. Especially the complex and often fragmented transition zones between dunes and salt marshes, and also those between beaches and dunes, could be restored and flourish again. All this asks for new policy and management strategies specifically for the Wadden Sea islands, not only to adapt to climate change and to fulfil the assignments from Natura 2000, but also to develop new ways of fitting in the characteristic human activities on the islands in a sound, safe and long-lasting way.

1.2 Trilateral Policy from the 2004 QSR up till now

On the trilateral level the Trilateral Wadden Sea Plan (1997) can still be seen as the most important document where specific targets regarding beaches and dunes have been formulated.

The Quality Status Reports of 1999 and 2004 have specified recommendations for the near future based on monitoring results from the previous period. The Quality Status Report 2004 (QSR 2004), Chapters 9.1 (Mulder *et al.*, 2005) and 9.2 (Petersen and Lammerts, 2005), gave an extensive description of the state of the beach and dune ecosystems in the Wadden Sea area. Much attention was paid to the presentation of the then newly developed TMAP typology of dune vegetation which was proposed to be included in the Trilateral Monitoring and Assessment Program. An overview was given of the distribution of TMAP types which had been extracted and translated from the vegetation maps then available. Also the increasing dominance of highly competitive grass species and some neophytes were treated. Additionally, some trends and developments in faunal communities were addressed briefly. This inventory was followed by a thorough analysis of the most important threats and perspectives for the Wadden Sea dunes. According to the QSR 2004 the main ecological problems were:

A. The development of a disturbed balance between natural successional stages, culminating in an under-representation of young (pioneer) and old (natural forest) stages and an over-representation of eutrophic mid-successional stages (especially those dominated by one or two very productive grass species).

B. The lack of natural sedimentation and erosion processes along large stretches of the coastline as well as within the older dune complexes by the anthropogenic suppression of sand blowing and periodical local overflow with seawater.

C. The atmospheric deposition of nitrogen compounds which during the last century increased to a peak of about 40 kg/ha/yr in the 1980s, decreased again to 27 kg/ha/yr in 2002 but still is above the critical loads of ca. 10-15 kg/ha/yr for nutrient poor, dry and wet pioneer vegetation types.

D. The quantitative and qualitative impact of active water management and drinking water extractions on the natural fresh-groundwater systems on the islands, especially on the dune slack ecosystems.

For beaches, it was concluded in the QSR 2004, that there was insufficient knowledge about the actual status of beaches in the Wadden Sea and, therefore, an evaluation of the targets was not possible. It was also underlined that growing human impacts due to increasing activities concerning coastal defence, as a consequence of climate change, as well as increasing recreational activities, imply an urgent need for information and reconsideration of the targets for beaches.

Targets

- Increased natural dynamics of beaches, primary dunes, beach plains and primary dune valleys in connection with the offshore zone.
- An increased presence of a complete natural vegetation succession.
- Favorable conditions for migrating and breeding birds.

Based on the inventory and the analysis, some recommendations were formulated (see text box below). On these matters there has been a fruitful exchange of ideas and knowledge in a trilateral dune conference in Wilhelmshaven on 28 August 2008, which was jointly organized by the National Park Administration Lower Saxon Wadden Sea and the CWSS. However, an effective cooperation leading to an intensive interchange of ideas or to common initiatives has not yet been achieved. Hereto a more powerful structure certainly is needed. Probably, execution of a common trilateral project involving dune research, exchange of experience and information, communication and practical experiments in dune management could be the basis for structural cooperation.

1.3 The actual state of the art

Many of the conclusions and recommendations of the QSR 2004 still apply nowadays. On the role of neophytes, the influence of atmospheric deposition and the role of active management there are no significant new developments to be reported upon. On four items, new data and/or new views will be presented in this report:

Recommendations on beaches and dunes in the QSR 2004

Recommendations for beaches:

- to reconsider the targets that are defined for beaches in the Trilateral Wadden Sea Plan;
- to add parameters to the TMAP that give information about the status of beaches in the Wadden Sea in relation to the targets;
- to use the information from research programs on the ecology of sandy beaches for the formulation of new targets and an appropriate monitoring program;
- to form an 'Expert Group Beaches' under the TMAG to carry out these recommendations.

The recommendations for dunes focus on different perspectives: management (coastal protection, water management, nature management), monitoring and research.

- Information on how dry and wet pioneer stages respond to different approaches of coastal defense should be communicated more effectively, and experiments should be carried out on the stimulation of natural dynamics. Special attention should be given to different ways of handling existing hard structures or substantial sand dikes, with the purpose of eliminating their restrictive influence on dynamic processes.
- An inventory should be made of the differences between the Wadden Sea islands in water management and of the ecological consequences. Where severe effects on dune slack vegetation can be demonstrated, measures should be taken to improve the situation.
- A discussion should be held among nature managers and policy makers on views of nature management, especially on differences in strategies aimed at reaching common goals, such as increasing natural dynamics and natural succession and maintaining biodiversity (at least at the level of the Habitats Directive requirements).
- The use of a harmonized monitoring program in the Wadden Sea dunes, recognizing the developed TMAP classification for dunes, species lists, cover, *etc.*, is a prerequisite for trilateral assessment of dune development and for the detection of trends. Such a program cannot operate without concurrent data collecting on atmospheric deposition, coastal protection measures and water management.
- Research should be stimulated into the possibilities of re-establishing very early pioneer stages in the outer dune area by stimulating dynamics in huge stabilized sand dikes ('constructed' by frequently repeated artificial sand trapping) or even by removing them locally. An integrated geomorphological and ecological approach must result in practical advice for coastal managers. In addition, more fundamental studies are necessary of the speed and direction of natural succession under different conditions. Such studies should include the lifespan of successional stages, dynamic equilibrium between such stages as influenced by human activities, as well as by large scale processes such as sea level rise and bottom subsidence. The outcome of these studies will contribute to the future policy and management questions concerning the Wadden Sea dunes.

1 Thanks to a more intensive vegetation mapping, the distribution of TMAP vegetation types can be updated. For the Lower Saxon islands, new mappings have been made of much higher quality and detail than the former ones. For some of the Dutch islands, reliable comparisons can be made between two high quality chronosequential mappings.
2 New concepts on island dynamics based on geo-ecological analyses on the Dutch and East Frisian Wadden Sea islands have been developed. Some examples of the applicability for nature management will be presented.
3 No progress has been made in forcing back the influence of groundwater extraction for drinking water production on the Wadden Sea islands, nor has any exchange of experiences and knowledge taken place since the QSR 2004. An update of the development of groundwater extractions during the last few years has been included in this report to stimulate activities on this subject in the years to come.
4 In general, it is more difficult for fauna- than for flora-elements to assess suitable management strategies to protect them. One of the reasons is the overwhelming number of species, at least when arthropods are included, and the small amount of information we have on their distribution. Additionally this complexity makes it very difficult to select species which generate information on the actual state of ecosystem components. The reason is that yet very little is known about the role of fauna groups within dune ecosystems. As a consequence, it is very difficult to define functional fauna groups, let alone to select the indicative species for such groups. However a more adequate nature management on the ecosystem level as well as the preservation of fauna biodiversity itself requires a filling up of these knowledge gaps. Adequate monitoring programs paralleled by scientific research on the role of functional animal groups or their indicators in ecosystem development are needed to meet these demands. Some possible approaches will be discussed.

The report will close with a short evaluation of trilateral targets and the formulation of some new recommendations.

2. Updating vegetation distribution maps

In the QSR 2004, a trilateral vegetation typology for Wadden Sea dune areas was presented. This new so-called TMAP typology (product of the Trilateral Monitoring and Assessment Program) was developed as a classification wherein all typologies of available local mappings of dune areas can be translated. A description of this typology is published in Petersen and Lammerts (2005). On the basis of this instrument, for the first time an overview could be given of the vegetation of dune areas in the whole trilateral Wadden Sea area. Some of the main conclusions were:

- Grey dunes cover larger areas in the Dutch and Lower Saxony dunes than in the North German and Danish dunes, while it is the other way round for dune heathland.
- Embryonic dunes are only sparsely present on the Dutch islands in comparison with the other islands.
- Only in very few dune slacks species rich pioneer communities occur; in particular, lime-rich vegetation is scarcely present.

Since 2004, several new vegetation mappings have been performed on some of the Dutch and all German Wadden Sea islands. On Texel (Everts and Pranger, 2006) and Vlieland (Bakker, 2005) completely new maps were made of nearly the same areas and on the same level of detail as the maps used for the QSR 2004. Only for these islands, vegetation *changes* over the last decade can be analyzed in considerable detail. In 2004, the complete terrestrial part of the National Park in Lower Saxony was mapped in TMAP units (Nature-consult, 2006). This mapping was done by a combined method of remote sensing, GIS and a very exhaustive field verification (Petersen *et al.*, 2008). The results are very exact in location and vegetation assignment. The older mappings, being the basis of the QSR 2004, had been performed by air picture analyses with very little field verification. As a consequence, a detailed comparison between the old and new mappings cannot be done in a way that sound conclusions on real vegetation changes can be inferred. Also in Schleswig-Holstein, new mappings have been executed between 2005 and 2007. While the islands are mapped on the level of Natura 2000 habitat types (TRIOPS, 2006; Leguan, 2006), St. Peter-Ording (Eiderstedt) is mapped in a detailed level of the TMAP typology (Nature-consult, 2008). The quality of the current data set is much higher than the data of the QSR 2004. Also here, a detailed comparison of old and new maps is not feasible. Moreover the level of detail of the old data sets is low.

For Denmark, recent mappings of dune habitat types according to the EU Habitats Directive are available. The habitat monitoring started in 2004 with monitoring of intensive and extensive stations. Data include vegetation cover, phytochemistry and soil parameters. There is public access to all terrestrial monitoring data, including species and habitat types, which have been gathered since 2004 on http://www.naturdata.dk/.

Table 1 gives a complete update of the QSR 2004 in the sense that earlier mappings are replaced by more recent mappings, when available. On a general level the results do not lead to adjustments of the main conclusions presented in the QSR 2004. However, important differences and changes may be hidden in the overall interpretation. For example, in Lower Saxony the interpretation of new, far more reliable vegetation maps leads to a decrease in coverage of lime-rich fen vegetation (H2.2), housing many Red List species, from 0.9 % to 0.2%. This is significantly lower than in the Dutch islands where no large overall change took place (from 0.9 to 1.0 %). These kind of trends, to be thoroughly analyzed, can only be assessed when reliable chronosequences of mappings from more sites and of a high quality become available. This emphasizes the need of continuation of a common (trilateral) approach of vegetation monitoring.

More than the results concerning content, the most important result of recent mapping activities probably is the increasing quality and quantity of maps available for analyses. For The Netherlands, Lower Saxony and St. Peter-Ording (Eiderstedt), the assessment of real vegetation changes will be possible in the near future. The same is true for Denmark, though the methods deviate from the mapping procedures in The Netherlands and Germany.

Table 1: Distribution of dune types in the Wadden Sea (update of Table 9.2.2 from the QSR 2004). For a translation of most TMAP types see the legend of Figure 1 (for more details on the TMAP typology see Petersen and Lammerts, 2005.)

TMAP types	X.3	X.4	X.5	X.6	X.7	X.7.1	X.7.2	X.8	X.8.2	H.0	H.1	H.2	H.2.2	H.3	H.4	H.5	H.6	H.8	
Natura 2000 types	2110	2120	2130	2140		2160	2170	2180		2190	2190	2190	2190	2190	2190	2190	2180	2190	
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	(ha)
NETHERLANDS	2.0	11.0	47.9	9.9	0.7	4.3	0.1	4.4	4.9	0.0	0.6	4.5	1.0	0.5	2.0	2.1	3.7	0.3	11312.4
Texel	0.6	12.9	44.4	9.0	0.6	5.4	0.1	5.7	3.7	0.0	0.4	3.6	2.6	0.4	1.6	2.2	6.1	0.3	3080.1
Vlieland	1.0	11.4	65.0	7.5	0.4	2.5	0.0	0.4	0.3	0.0	1.3	2.4	0.9	2.1	4.4	0.3	0.0	0.0	1046.9
Terschelling	3.0	10.7	40.1	18.4	0.0	0.6	0.3	3.8	11.2	0.0	0.5	5.4	0.6	0.6	1.1	2.0	1.4	0.1	3915.3
Ameland	1.6	6.5	60.0	2.2	2.5	2.1	0.0	8.3	0.0	0.0	1.1	6.7	0.0	0.2	4.2	3.0	0.8	0.8	1997.8
Schiermonnikoog	4.0	14.0	46.9	0.0	0.1	17.9	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.6	2.5	12.2	0.0	1272.3
Niedersachsen	6.2	15.6	41.6	3.7	5.8	5.9	4.7	3.7	0.9	0.0	0.2	3.0	0.2	0.1	2.4	1.5	4.1	0.4	4737.2
Borkum	2.1	11.1	36.8	0.5	6.1	6.5	9.4	5.6	0.6	0.0	0.1	4.4	0.9	0.1	3.7	3.1	9.1	0.1	1241.9
Juist	4.5	18.0	34.7	0.6	15.0	9.3	4.2	1.9	1.0	0.0	0.0	0.6	0.1	0.0	2.3	2.4	1.4	3.8	496.5
Memmert	6.7	24.4	52.1	0.0	0.3	7.1	1.1	0.2	0.0	0.0	0.0	6.0	0.0	0.0	1.8	0.1	0.0	0.2	42.5
Norderney	8.9	19.4	44.6	1.4	1.2	1.5	5.3	2.4	1.3	0.0	0.1	4.3	0.1	0.4	3.9	0.9	4.3	0.1	1078.2
Baltrum	6.4	14.2	52.3	0.1	4.0	10.5	3.3	1.8	0.5	0.0	0.4	3.1	0.1	0.0	0.2	0.9	2.2	0.0	272.4
Langeoog	8.5	16.4	37.0	11.1	5.0	11.6	1.3	3.0	0.0	0.0	0.8	2.5	0.0	0.1	1.3	0.1	1.3	0.0	682.8
Spiekeroog	8.6	16.6	43.3	11.0	4.7	3.3	1.6	6.2	01.8	0.0	0.0	1.0	0.0	0.0	0.2	0.1	1.3	0.1	521.4
Wangerooge	0.6	14.3	44.5	7.0	15.0	3.3	0.6	5.3	2.2	0.0	0.0	1.3	0.0	0.0	1.3	2.0	2.4	0.1	245.6
Mellum	24.8	19.5	54.0	0.0	0.7	0.7	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	59.0
Minsener Oog	1.1	10.3	83.8	0.0	3.2	0.6	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.8	0.0	0.1	96.9
Mainland coast	0.0	3.6	20.9	8.3	3.1	0.2	0.4	10.1	1.2	0.0	0.0	15.8	0.0	0.0	33.1	0.3	3.1	0.0	205.1
Hamburg	9.1	40.2	46.9	0.0	0.5	0.0	0.1	0.0	0.0	0.0	0.0	1.1	0.0	0.0	2.1	0.1	0.0	0.0	45.1
Schleswig-Holstein	9.9	12.2	24.5	41.9	0.1	0.0	2.5	0.2	0.0	7.9	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	3652.7
St. Peter-Ording	35.0	21.3	7.4	3.3	4.7	0.0	5.9	0.0	0.0	0.0	0.1	0.1	0.0	0.0	22.2	0.0	0.0	0.0	103.7
Föhr	14.9	0.0	85.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7
Amrum	25.5	16.7	33.4	18.0	0.0	0.0	5.3	0.7	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1044.9
Sylt	2.3	9.8	21.6	53.7	0.0	0.0	1.2	0.0	0.0	11.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2498.3
DENMARK	7.5	2.2	34.8	35.1	0.0	0.0	0.6	0.3	7.7	11.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3077.1
Römö	21.5	4.0	12.2	37.7	0.0	0.0	1.1	0.0	22.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1076.5
Mandö	0.0	0.0	92.6	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27
Fanö	0.0	0.1	43.6	34.2	0.0	0.0	0.3	0.5	0.0	21.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1650.4
Skallingen	0.1	7.3	56.6	35.9	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	323.2
WADDEN SEA AREA	5.8	11.0	40.9	17.0	1.6	3.3	1.5	3.1	3.6	2.8	0.3	3.0	0.5	0.3	1.6	1.4	2.7	0.2	23029.6

Comparing two chronosequential mappings on the island of Texel illustrates the importance of monitoring vegetation changes for nature management and policy. Changing natural processes or management influences can be assessed which makes it possible to adapt management strategies if necessary. On Texel, some of such changes in two succeeding mappings (Figure 1) are clear, especially when looking to the developments between 1997 and 2006 in the dune slack areas on the south side of the island:

1. the areas with reedbed vegetation have decreased between both mappings;
2. there appears to be a clear increase in lime rich fen vegetation in the dune slacks;
3. the area with open water and water vegetation increased considerably;
4. in the dry dunes some productive grass species reached dominance in larger areas.

The changes probably are caused by a gradual rise of the groundwater table due to stopping groundwater extractions for drinking water production. Also, in an ecological restoration project, the outflow of fresh surface water from the system has been restricted. Moreover, the coastline has expanded considerably during the last twenty years as a consequence of increasing sand sedimentation along the southern coastline. This leads to a considerable growth of the fresh water body below the dunes.

Another important factor may be the introduction of cattle grazing which has led to the development of more open vegetation in and along the dune slacks. In the drier parts, on the other hand, it seems that the cover of closed grassland vegetation has increased. This effect in dry dune areas is especially known from old dunes where the topsoils are decalcified. Under these circumstances grazing appears to stimulate the development of closed grasslands with Festuco-Galietum vegetation.

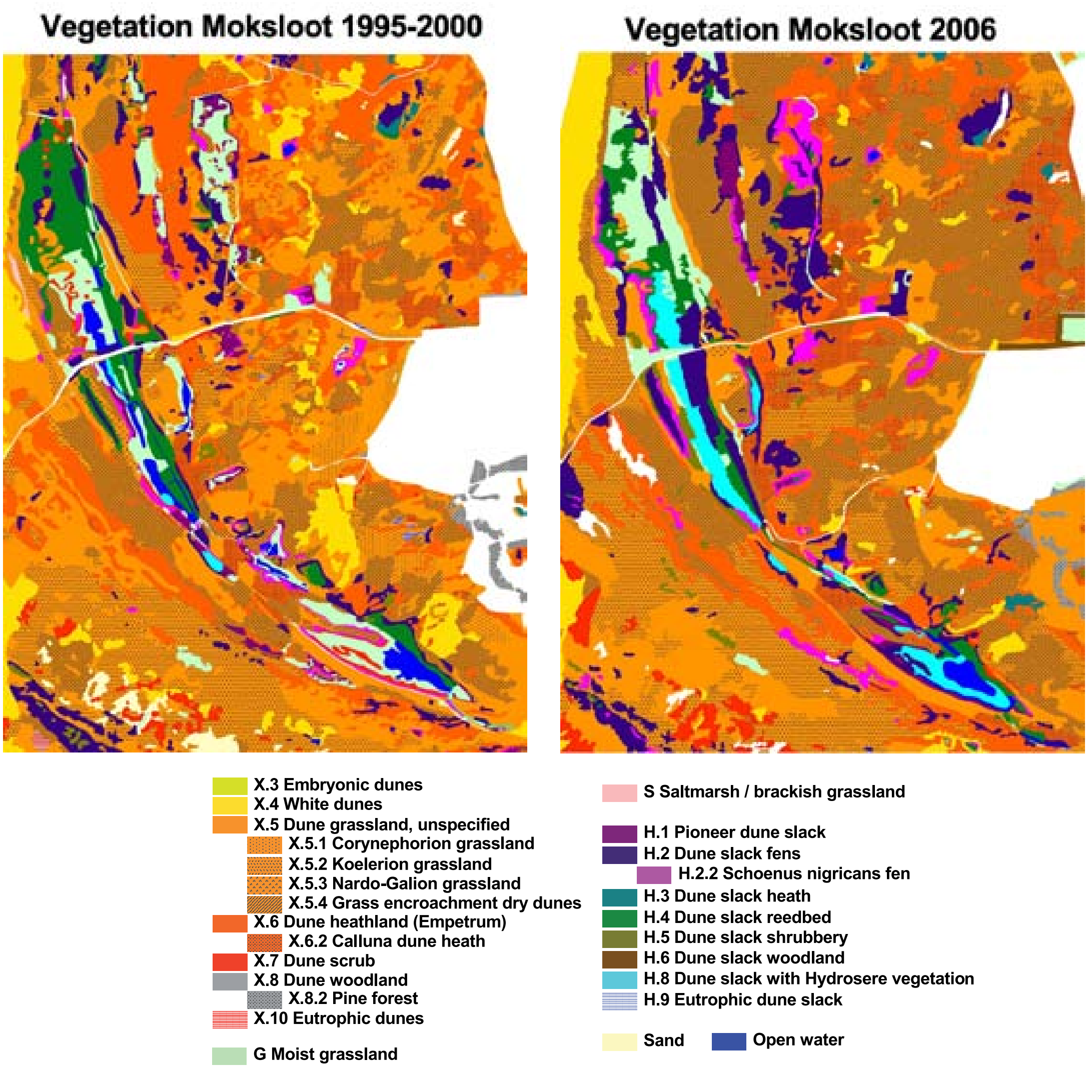


Figure 1: Vegetation maps of south Texel from 1995-2000 and from 2006; local vegetation types are translated to TMAP types.

3. New geo-ecological concepts

Since about a century ago, the nature areas on the Dutch Wadden Sea islands show gradual but large changes in dominating habitat types. In all vegetation series (halosere, hydrosere, hygrosere and xerosere), young successional stages have gradually been replaced by older stages. Grass and bush encroachment caused decreases in the area of open, low vegetation stands and in the number and area of patches of bare sand or mud. As a consequence, small scale biodiversity in dunes and salt marshes, not only of higher plants but also of mosses, lichens and insects, has declined. Nowadays some of the most characteristic species, including some of the birds typical of open dunes, have vanished completely from the islands.

Successional development on the site is a natural process as such. On the Wadden Sea islands, however, vegetation regression, periodical 'destruction' of vegetation-covered surfaces caused by dynamical processes such as water erosion or blowing sand, is an equally natural process. The equilibria between building and degrading forces on different spatial and temporal scales determine the patterns in vegetation and habitat types on the islands. The actual unbalance where old grass and bush encroached areas seem to replace younger successional stages almost completely mirrors last century's dominance of men's stabilization measures over natural processes. Therefore, from an ecological point of view, the rehabilitation of natural dynamics recently is often propagated.

The necessity to implement Natura 2000, as well as the expected climatological changes, stress the need to re-orientate coastal and nature management strategies for the Wadden Sea Islands. In this process, the apparent contradiction between natural dynamics and traced Natura 2000 habitats should be met and the effects of stimulating natural dynamics on coastal safety analyzed. A group of ecological consultants and scientific researchers in The Netherlands responded to the challenge. As a first step they identified the most important driving forces on different spatial and temporal scales. Next they identified five main components with their sub-elements on a 'model island', each controlled by a specific set of more or less dynamic geomorphologic and hydraulic/hydrological processes. The results can be found in a more general publication (Löffler *et al.*, 2008) and two reports with background information: an ecological study (De Leeuw *et al.*, 2008) and a geomorphological study (Ten Haaf and Buijs, 2008).

The model (Figure 2) has been developed for the west-east orientated islands along the Dutch and Lower Saxony coast. On this model island, five main components have been distinguished (Löffler *et al.*, 2008). They are characterized by the specific spatial and temporal scales of the processes determining the speed and frequency of natural successional and regressional changes between and in the sub-elements (numbers according Figure 1):

1. Island Head: The development of the island head depends on the sedimentation and erosion processes in the deltas between the islands. Periodically bare beach plains unite with the eastern island: at the north side when the sand comes from the outer delta and at the south side when it is coming from the inner delta. When there is enough sand available, embryonic dunes and dune ridges may develop, with brackish marshes and dune slacks in between. All these different sub-elements are almost permanently subject to dynamic processes and have a lifespan

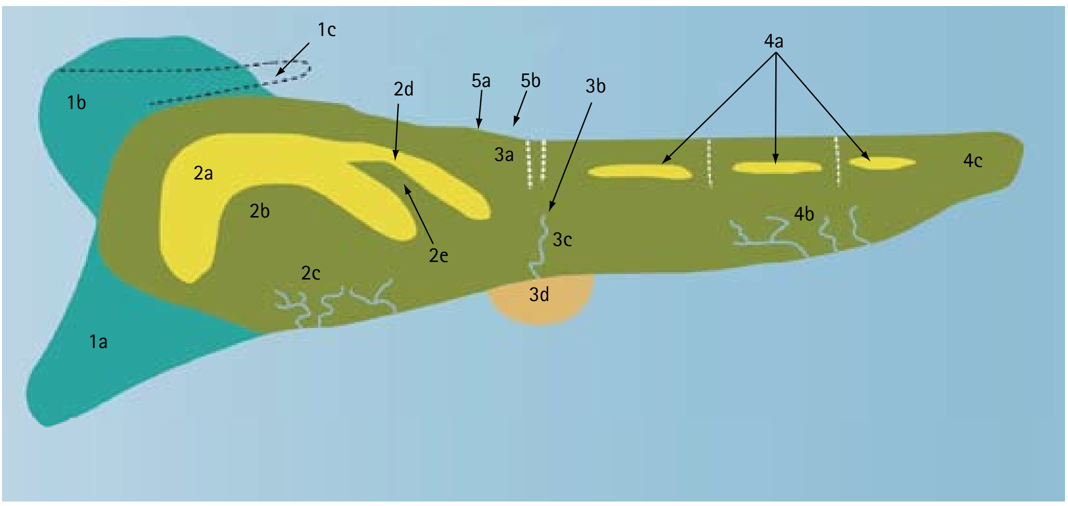


Figure 2: The geo-ecological model island with its characteristic main components and sub-elements (for details see text) (after Löffler *et al.*, 2008).

of 25-50 years. At the inner side, more stable elements can develop: even grey dunes (mostly of the lime-rich type) may temporarily be present. After a while, steep tidal inlets will approach the coast and break down the island head again (on western Ameland about every 60 years; *pers. comm.* Dr. A.P. Oost). The eroded sand then moves along the North Sea coast leading, to periodical sedimentation and erosion there.

2. Dune Bow Complex: The dune bow complex comprises an old central part of the model island, where much sand has been blowing in during long periods of sedimentation. The quantities have been so large that different dune ridges merged to large parabolic dune systems which often have been secondarily reformed to all kinds of dune forms. Until about 1900, stabilization by ongoing succession to scrub and woodland has been retarded by all kinds of intensive human use, such as sod-cutting, mowing, grazing, even periodical burning, *etc.*. Although it takes a long time before organic matter accumulates substantially due to the nutrient poor character of the substrate, dune bow complexes tend to stabilize in the long run. In a natural configuration, it houses a great variety of sub-elements, such as all kinds of grey dunes and heathlands, dune lakes, marshlands and dune slacks, even peat- or bog-forming patches at the inner- and outer dune fringes, *Hippophae*- and *Salix*- shrubs, dune woodland, especially in older decalcified slacks, *etc.*. Salt marshes develop a the Wadden Sea side of stable dune bow complexes and will be there as long as the dunes protect them. However, many of them have been embanked in the past. The sub-elements may have a short lifespan (*c.* 50 years) when subject to secondary dynamics; and up to a very long lifespan of many centuries when stable conditions prevail, *e.g.* in peat-forming systems.

3. Washover Complex: A washover consists of a north-south orientated part of the beach plain accompanied at both sides by natural dune ridges. Here, during high tides, overwash of sea water from the North Sea occurs. An interweaving of several such washovers along the eastern border of a dune bow complex appears to be characteristic for the west-east orientated islands. Most clearly on Spiekeroog, but also on Noderney and Borkum, such washover complexes can still be found in an active state. On the Dutch islands, no active washover complexes are present any more, all of them being closed by sand dikes. The remnants can, however, be quite easily recognized. At the west side, the washover complexes are bordered either by another dune bow complex (on Ameland there even are three dune bow complexes separated by two former washover complexes) or by a large beach plain. Very characteristic for washover complexes is that large sandy areas are covered with different types of algal mats which seem to hamper further succession, probably by forming a resistance to the settlement of higher plants as well as by their vulnerability to erosional processes. Besides these beach plains and the parallel dune ridges, all kinds of sub-elements can be considered to be characteristic for this main component: embryonic dunes, white dunes, dune grasslands, small patches with fen vegetation at the foot of small dune elements, sandy to muddy salt marshes and salt water creeks coming from the North Sea side as well as from the Wadden Sea side (though mostly not interconnected all over the island). Depending on the extent to which these sub-elements are subject to more or less dynamic conditions, their lifespan may be somewhere between 25 and 100 years. All of them undergo long periods with sedimentation (by inblowing sand and locally by inflowing sea water). Some of them are subjected more or less frequently to very short periods of severe erosion during storm tides. As a net result, the washover complex as a whole appears to be a very stable main component, which may be present at the same site even for centuries.

4. Island Tail: The island tail consists of a beach plain at the eastern side of the island. The stability of this main component depends on the dynamics on larger spatial scales than the component itself. In a period of long-lasting sedimentation along the North Sea coast it may develop into a closed dune bow complex. In a period of strong erosion, the whole island tail may disappear again in the long run. However, it seems that it can be present for a long time when it is only subject to periodical net sedimentation and net erosion. The dune sub-elements are comparable to those present on the island head: embryonic dunes, white dunes, partly closed dune ridges with primary dune slack fens, even locally lime-rich grey dunes, *etc.*. Here too, the sub-elements will have a lifespan of about 25-50 years. On the island tails, several individual washovers are also present. As in the large washover complexes, they probably give certain long term stability to the island tails as a whole. Very characteristic for the island tails is the presence of salt marshes. In general, they have a far more muddy character than the brackish marshes on the island heads. It seems that the gradient of pioneer to old salt marshes, intermingled with enclosed permanent wet areas

and natural pattern of creeks, is rather complete when the island tail shows a dynamic structure without artificially closed sand dikes at the North Sea side. In such "natural" circumstances, the area with characteristic salt marsh vegetation however is smaller than behind such dike structures.

5. Beach and Foreshore: From a geo-ecological point of view, the last main component, the beach and foreshore at the North Sea side, can be considered as a very important functional element as transport route for sedimentation and erosion products. Beside that function it can temporarily provide substrate for embryonic dunes and green beaches with very high biodiversity (see also text box on Schiermonnikoog).

The geo-ecological approach, presented here, appears to be very promising as a basis to identify deviations from natural courses in developing successional series. At the same time it also leads to hypotheses of how to restore geomorphologic and ecologic processes in such a way that they fit in again with the temporal and spatial scales of the "original" or "natural" course of succession. Schiermonnikoog shows a fine example of such considerations (see text box below).

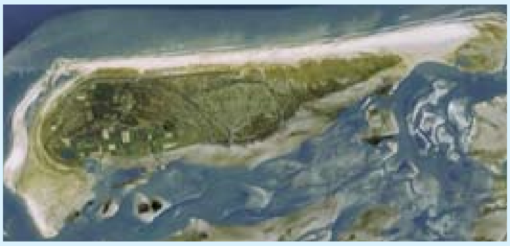
Geo-ecological analysis of recent developments on Schiermonnikoog

The pattern of main components on Schiermonnikoog shows a large resemblance with the model island (Picture 1). Since the last 50 years, two very distinguished geo-ecological changes on the island occurred which had significant effects on the ecological functioning of some of the main components (Picture 2):

1. Closing off the Lauwerszee from the Wadden Sea in 1969 reduced the adjacent water catchments in the Wadden Sea. This had a considerable increasing effect on the amount of sedimentation of sand along the west coast of Schiermonnikoog and next led to a huge sedimentation almost all along the North Sea beach of the island. During the last 20 years, large areas on the beach became vegetated.

2. In 1959, a huge washover complex east of the dune bow complex was closed by the construction of a sand dike of about 4 km along the North Sea beach.

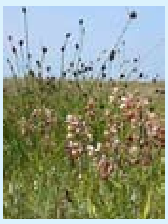
Where the green beach borders the dune bow complex, it shows a geomorphologic structure and vegetation composition which is completely different from where it borders the former washover complex. North of the dune bow complex, a large green beach with an evened surface developed (Picture 3), housing a homogeneous and very species rich fen vegetation, characteristic of fresh water fed, lime-rich dune slacks (Picture 5). Probably, there is a very high and stable groundwater level caused by the recent seaward expansion of the coastline which led to the growth of the freshwater body below the dune bow system. Of course, at high tides, the vegetation gets inundated with sea water. However, this salt water flows off very fast again because of the permanent saturation with fresh water of the top soil. North of the former washover complex, the geomorphologic structure as well as the vegetation composition, are far more heterogeneous (Picture 4). Because of the absence of a massive dune system in the hinterland, there is no influence of a fresh groundwater body on the beach

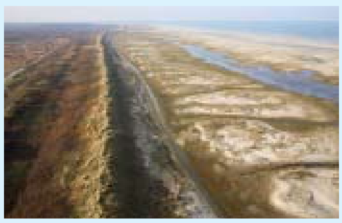

Picture 1


Picture 2


Picture 3


Picture 4


Picture 5


Picture 6

and the top soil will run dry in the absence of inundating sea water. Under such conditions the influence of wind blowing may be very dominant and complexes of embryonic dunes with scarce pioneer vegetation developed. If at high tides salt water is flowing over, it apparently grinds away natural creeks through the young dune systems at regular distances, a few large ones west-east and many smaller ones north-south (Picture 6).

It must be realized that as rapidly as the green beaches and the high biodiversity on them developed, they can disappear again in future decades. Their fate depends on the course of the large scale dynamic processes of the main component beach and foreshore. On the basis of old vegetation maps, a reconstruction has been made of the situation before the sand dike closed off the former washover complex. Many of the species rich gradients, now present on the green beach, then were present on the middle of the island in a wind- and/or water- deposition zone of the washover complex (Figure A). After the construction of the dike, the hinterland gradually stabilized. In c. 1995 the younger successional stages had disappeared almost completely (Figure B; also visible on Picture 6). It is very plausible that without the dike and under the actual circumstances, the dominant geo-ecological processes would now also have been very influential up until halfway the island. This would have guaranteed a more lasting presence of pioneer stages up until the centre of the island, also when sedimentation conditions on beach and foreshore turn into erosion conditions. It may be very worthwhile to explore the possibilities to execute restoration measures which bring the concerning main elements of the islands back in phase again with the characteristic spatial and temporal scales of the dominating natural processes (cf. Figure C).

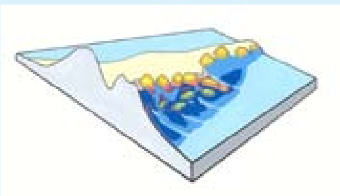


Figure A. Situation 1959

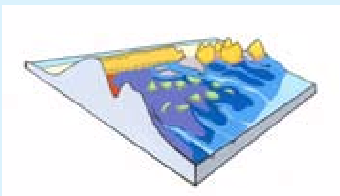


Figure B. Situation ca. 1995

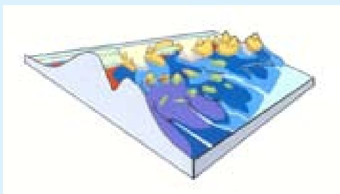


Figure C. After ecological restoration ?

Legend Figures A-C
(Reconstructions A.P. Grootjans)

This geo-ecological approach may also be a sound basis to identify natural sites for (complexes of) Natura 2000 habitats. From the descriptions of the main components, it may be obvious that the right conditions for some habitat types are available in one main component and hardly or not at all in another. This is crucial for the localization of Natura 2000 sites. In general, it may be stated that, for pioneer habitats, the island head and tail are much more suitable than the other main components. On the other hand, the dune bow complex offers better perspectives for some types of grey dunes, dune heath lands, dune woodland, fresh dune marshes and locally some peat- and bog- forming habitats. The approach also may give indications of how and where to stimulate the development of habitats, which are absent now, by restoring the geomorphologic basic conditions. Figure 3 gives the natural position of island habitats projected on the model island. For each individual island this can be further implemented by taking the actual state of the main components into account.

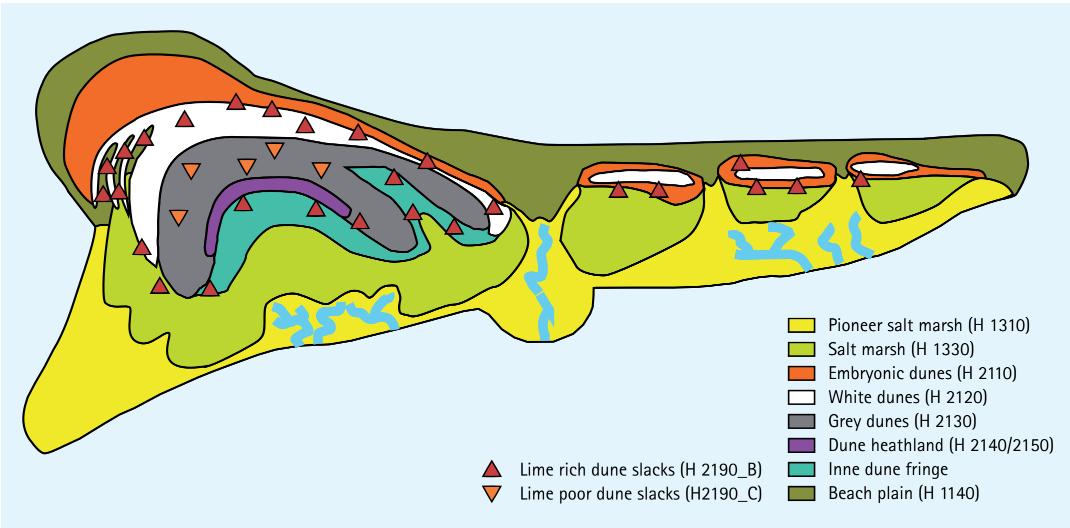


Figure 3: The natural position of Natura 2000 habitats projected on the geo-eco-logical model island.

4. Groundwater extraction on the islands

In the QSR 2004, the problems concerning groundwater extraction for drinking water production were extensively analyzed. It was concluded that since the 1980s a sound scientific basis has been established to identify and predict the ecological effects on natural dune slacks. It was observed that dune slack vegetation suffered severely when influenced by changes in groundwater regime such as lowering and increasingly fluctuating groundwater tables, as well as changing flow patterns and groundwater chemistry. It also became clear that there were huge differences in the actual practice of groundwater extractions between the islands and also between the countries. Political or managerial considerations of water companies and public authorities probably seemed to lead to very diverse decisions on extraction practices. On small islands with small fresh water bodies huge withdrawal were sometimes allowed, apparently without much regard on ecological effects, while on larger islands a much more cautious approach of smaller groundwater extractions was adopted. It was recommended that priority should be given to:

- organizing the exchange of information and knowledge between all regions;
- assessing the state of the art concerning the magnitudes of groundwater extractions on the Schleswig-Holstein and Danish islands;
- ecologically optimizing the extraction methods (and location choices) on all islands including ecological biomonitoring (Petersen *et al.*, 2003, Petersen and Lammerts, 2005).

In the last few years only little progress has been made concerning this subject. In general, there has not been a decrease in groundwater extractions, as can be seen in Figure 4 showing an updated graph since the QSR 2004. A remarkable aspect is the very large groundwater extraction (2.2 million m³/year) on Sylt which was not yet included in the last overview. The results of biomonitoring during the last ten years on Norderney and Langeoog, however, have led to some decreasing ecological effect of water extraction. On Borkum, on the contrary, biomonitoring was not applied and the effects on dune slacks have not decreased at all. This is all the more regrettable because on Borkum, of all Lower Saxony islands, the best developed lime-rich fen vegetation in wet dune slacks is present (Petersen, 2000; Petersen and Pott, 2005).

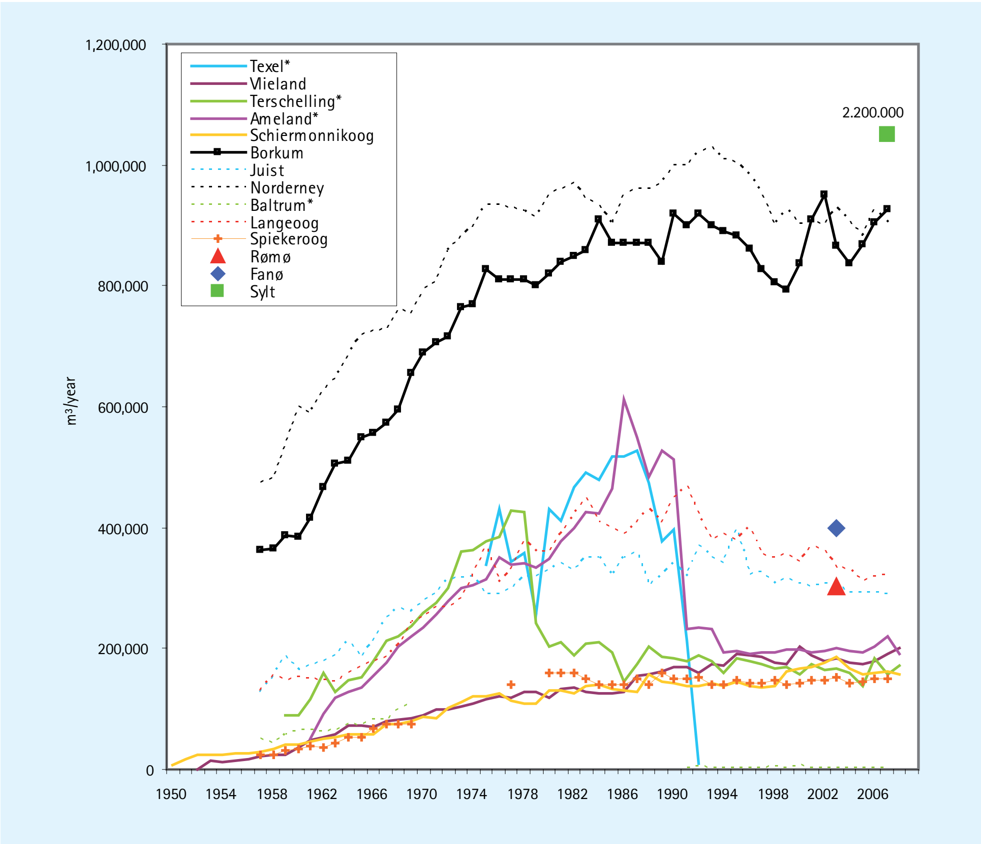


Figure 4: Groundwater extractions on the Wadden Sea islands (in m³/year); asterisks indicate islands which are totally or partly provided with drinking water from the mainland.

5. The status of dune fauna

In contrast to our knowledge of dune vegetation, the knowledge of dune fauna is still scarce. Studies on the bird fauna predominated during the last decades and we have a thorough knowledge of population trends in birds (*e.g.* Koffijberg *et al.*, 2006). The high importance of the Wadden Sea for hibernation and foraging justified the high priority of birds in conservation and the bird monitoring definitely needs to be continued. Unfortunately, our knowledge of the rest of the fauna is very incomplete. The dune islands of the National Park Lower Saxon Wadden Sea are probably the best studied areas in the Wadden Sea concerning the invertebrate fauna. A comprehensive checklist of the fauna is available (Niedringhaus *et al.*, 2008), which probably covers about 75% of the existing fauna. Although this study represents probably the most complete faunal checklist for a part of a European National Park, some taxa are still understudied (*e.g. Diptera*). Arthropods are by far the most diverse group on the islands, but our knowledge on these species still remains fragmentary. The existing data have mainly been obtained during mapping projects in the 1980s and 1990s, performed by the University of Oldenburg (*e.g.* Haeseler, 1988). The information gathered from these mapping projects included species lists, but also data on habitat affiliation. This comprehensive knowledge on biodiversity on the dune islands is an excellent basis for future studies. On the other hand, the existing knowledge is purely descriptive. A better understanding of the interactions between anthropogenic habitat changes and faunal biodiversity trends is needed to assess observed changes. Data on habitat requirements or population trends of endangered arthropod species is almost completely missing. Continuous monitoring programs should, therefore, be implemented in order to obtain information on the population trends of endangered species. Below three monitoring approaches will be presented.

Approximately 8,000 animal species have been recorded from the East Frisian islands, and it has been estimated that around 10,000 animal species exist (Niedringhaus *et al.*, 2008). Obviously, it will be impossible to monitor all of these species. Hence, a priority list needs to be established, identifying a set of indicator species or high priority species that should be monitored periodically. This list should include *c.* 100 arthropod species that either have their main distribution in the dunes or are highly endangered. This information can be obtained from the checklist provided by Niedringhaus *et al.* (2008) or from the data collected by EIS Nederland. The monitoring frequency should be *c.* 3-5 years, but care must be taken to develop a specific program for each species as some arthropods might have a two year life cycle (*e.g. Decticus verrucivorus*). A major goal of monitoring programs is to gain information on population trends of endangered species. This can help to identify threats or sudden population breakdowns.

A second important approach to obtain data on population trends is to repeat old mapping projects at exactly the same locations and with similar methods. This may provide data on population trends, extinction and colonization processes. A major problem is that no data for the time between two data sets exist, so that the natural population fluctuations cannot be reconstructed. However, based on presence-absence data, the identification of declining species is possible, which can help to update the monitoring species list. The fundamental difference between the monitoring approach and the re-mapping approach is that the first method aims at minimizing the temporal and financial investment and optimizing the information needed for long term management strategies, while the second method will gain data on a higher number of species at much higher costs. An optimal strategy will combine both methods. A re-mapping project might be started at intervals of twenty years, while monitoring should be repeated every 3-5 years.

A third approach, possibly providing the most important information needed for developing a sustainable management, is research on invertebrate responses to dune management. During the last decades, a number of new management techniques has been executed, but the evaluation of these methods has solely relied on vegetation data. As most invertebrates respond to a combination of changes in the vegetation composition, vegetation structure, abiotic factors and biotic interactions with other animal species, the response of the vegetation cannot be simply transferred to the fauna. A research project needs to be started that (1) compares the faunal diversity and particularly the presence of highly specialized or highly endangered species in dune slacks with different management; and (2) studies the faunal succession after new management practices have been implemented. Again, it will not be possible to study all animal groups during such a project, but some highly diverse groups (*e.g. Hymenoptera, Coleoptera, Araneae*) should be included.

In addition to the above monitoring approaches, it may be essential for the conservation of a species to obtain knowledge on its habitat requirements. Key factors for the survival of highly endangered or specialized dune arthropods have to be unraveled in order to optimize management strategies. This knowledge is particularly important for species which occur mainly or only in the dunes of the Wadden Sea, such as the bug *Monosynamma maritima* (Niedringhaus *et al.*, 2008). Autecological data for endangered dune insects are still sparse. A recent example is the study on the habitat preferences of Cepero's ground-hopper *Tetrix ceperoi*, which has its largest Central European populations on the Wadden Sea islands (Gröning *et al.*, 2007). Autecological studies can be included in the monitoring program: The main program should focus on population trends, but at greater time intervals, autecological studies for single priority species can be included.

Last but not least, it is worth mentioning that nowadays some research is executed on the effects of habitat changes in dunes on food webs. Though up until now primarily motivated by the desire to understand the decline of characteristic dune birds, a further development of this approach may be the start of a better understanding of the fate of many more fauna groups on different levels in complex foodwebs. It will probably also provide information on the role of biotic ecosystem processes such as competition and facilitation. These may be important key factors which can be influenced by nature management strategies. Further information on this subject is included in the textbox below.

The importance of food web analyses for understanding effects of habitat change on dune animals

In coastal dunes of the Netherlands – as well as in other parts of Western Europe - increased atmospheric deposition (acidification and eutrophication), lowered groundwater levels, decrease of rabbit populations and changes in land use cause encroachment by tall grasses and bushes. Open and species rich succession stages decreased as well as variety in vegetation structure. The resulting lack of heterogeneity in the dune landscape has negative consequences for the fauna. Since monitoring data from the past are lacking for most animal species it is hardly known which species have seriously declined. However, extinction or strong decline of predators such as red-backed shrike, Northern wheatear, hen harrier and short-eared owl indicates that major shifts in the food web of the Dutch dune system have taken place during the last decades.

It was found that breeding success of red-backed shrike depends on a high availability of large insects and small vertebrates. This makes the red-backed shrike a good indicator of arthropod abundance. To detect which animal species have decreased or vanished from the Dutch dunes, breeding and food ecology of the last red-backed shrikes in the Dutch dunes (1997-1998) was compared with the ecology of a vital population in comparable intact coastal dunes near Skagen, Denmark. This Danish population has a density which is comparable with the situation in Dutch dunes at the beginning of the twentieth century (± 40 breeding pair on 1100 ha) and breeding success is high and stable throughout years. It turned out that prey items in the nestling diet in Denmark were on average twice as heavy as prey items in the Netherlands. Due to the lack of sufficient large prey species in the Netherlands the adults had to put more effort in feeding their nestlings, which resulted in a low breeding success. According to the diet it is concluded that the food web in coastal dunes near Skagen is still fairly intact. Main prey species in Denmark were the scarabid beetle *Anomala dubia*, Wartbiter (*Decticus verrucivorus*), sand lizard (*Lacerta agilis*) and bumblebees (*Bombus* sp.). All these species (groups) declined or disappeared from Dutch coastal dunes prior to the extinction of the red-backed shrikes. In Denmark the massive hatching of grass-root feeding *Anomala dubia* and the breeding season of the red-backed shrike seem to be synchronised. A bottleneck analyses for this beetle species revealed that sand-spray appears to influence the densities of larvae of *Anomala dubia* indirectly. Few or no larvae were found in stabile parts of the dunes, whereas high densities were found in case of sand-spray. The density of larvae is highest in sites where Marram grass *Ammophila arenaria* is vital and makes new shoots. Here, the vitality of root growth probably determines food availability for the larvae. Microclimate (temperature and moisture) in the soil seems to be a relevant factor in speed of larval development. At sites with sand-spray larval development seems to be completed in one year, whereas it takes two years in less dynamic sites.

Also for the last populations of Northern wheatear in Dutch coastal dunes, scarabid beetles as well as other root-feeders such as click beetles (Elateridae) and caterpillars of moth species seem to be very important prey items which contribute up to 70% of the total diet. In many cases these prey items are still present, but the high grass makes them unattainable for the foraging bird species.

The study on the food ecology of red-backed shrike and Northern wheatear proved to be an excellent tool to identify changes in the food web and faunal diversity caused by degradation of coastal dunes. Next to root eating invertebrates (scarabid beetles and click beetles, caterpillars of moths) also thermophilous carnivores (Sandlizard and Wartbiter) and above-ground herbivores and flower visiting insects - mainly (caterpillars of) moths and bumblebees – were showed to be important animal groups which have declined in Dutch coastal dune ecosystems.

Contribution Stichting Bargerveen, Radboud University Nijmegen 2009.

Further information can be found in Kuper et al. (2000), Nijssen et al. (2001) and van Duinen et al. (2005).

5. Target evaluation

An extensive evaluation of the realization of trilateral targets was carried out in the QSR 2004. Below some recent developments concerning the evaluated targets from the Trilateral Wadden Sea Plan (1997) will be discussed briefly:

Increased natural dynamics of beaches, primary dunes, beach plains and primary dune valleys in connection with the offshore zone.

The tendency of some less strict coastal protection leading to a little more wind erosion in the outer sand dikes has continued. However, a management strategy relying on natural geomorphological processes is still far from achieved. In this context, the implementation of the new geo-ecological approaches presented above might lead to a breakthrough in coastal and dune management.

An increased presence of a complete natural vegetation succession.

In the QSR 2004, it was concluded that atmospheric deposition of nitrogen declined and that in the future only local problems would remain. The main problem was thought to be how to get rid of the high standing crop and the large litter layers which had been built up during the periods of highest deposition. Nowadays, there is some doubt about the accuracy of the deposition figures. In the wet dunes, the application of management tools such as sod-cutting and mowing have locally led to regeneration of pioneer stages on mineral soils. The surplus of organic matter in the dry old dunes, however, is still present and increasing. Another problem already addressed in the QSR 2004 involves human influence on the natural hydrological systems, especially groundwater extractions. It is evident that there are still large differences between the countries and between single islands.

Favorable conditions for migrating and breeding birds.

The consequences of habitat changes for migrating and breeding birds were indicated in the QSR 2004. Recent research on the effects of habitat changes on food webs (see above in the textbox on food web analyses) produces promising results concerning the detection of key factors on an ecosystem level, determining the decline of characteristic breeding birds of open dunes such as the red-backed shrike and the Northern wheatear. This approach leads to practical recommendations to nature managers.

6. Recommendations

Management of beaches and dunes are organized in very different ways within and between the three countries. However, to handle the important actual ecological problems in the Wadden Sea dune areas, a trilateral approach will be very fruitful, if not necessary with respect to climate change. For this purpose, an intensification of interchange of knowledge and experience is needed, both on the level of long term management strategies and on the level of practical management measures. A trilateral platform on nature policy and management on the Wadden Sea islands, consisting of scientists of different disciplines (ecology, geomorphology, hydrology, geochemistry) and representatives of nature management authorities will be needed. In the long term, however, this will only be effective when common projects are initiated concerning research, communication and the execution of experiments in the field. Trilateral fund raising from international funds, especially on EC level, may be highly successful in realizing such projects.

Specific recommendations on the basis of this report are:

1. The periodical vegetation mapping on the Wadden Sea islands (once per decade) must be continued. For some of the islands, the quality of vegetation mapping must further be improved to be able to assess vegetation changes and their causes on a comparable level of reliability.
2. The new geo-ecological approach must be further refined by studying for each main component the key processes determining the patterns at the scale of sub-elements. Moreover the approach should be extended to cover also the north-south orientated Wadden Sea islands in Schleswig-Holstein and Denmark. Experiences with the application of the new concepts for nature planning on behalf of the implementation of Natura 2000 should be shared trilaterally.
3. As already recommended in the QSR 2004, it is necessary to organize a trilateral exchange of knowledge on the ecological effects of groundwater extractions, especially on ways to ecologically optimize drinking water production (*e.g.* by extracting from other locations or deeper aquifers, by applying new desalination techniques on sea water or brackish or salt groundwater).
4. In nature management on the Wadden Sea islands more attention should be paid to the role of fauna elements other than birds. General monitoring and mapping projects should give more information on the occurrence of insect species. Specific monitoring may shed light on the direct effects of management techniques on fauna communities. Auto-ecological studies of indicative species and studies on the structure and functioning of food webs will give more insight in the key factors to focus on in nature management. It will be necessary to discuss among faunal specialists and nature managers what the most effective mix of these approaches is and where priorities should be laid.
5. The recommendation for beaches as given in the QSR 2004 (reformulation of the targets of the Wadden Sea Plan, adaptation of the parameters of the TMAP, inclusion of results of research programs and establishment of an expert groups) are still valid and should be reconsidered.

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