9. Beaches and Dunes

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9.1 Beaches

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Beach plain on the island of Rømø with whithe dunes and typical tourism use (Photo: J. Petersen)

9.1.1.Introduction

During the Stade Conference in 1997 the Trilateral Wadden Sea Plan was adopted with common Targets for habitats species. The following Targets are valid for the habitat 'Beaches and Dunes':

Targets

- Increased natural dynamics of beaches, primary dunes, beach plains and primary dune valleys in connection with the offshore zone.
- Favorable conditions for migrating and breeding birds.

In the 1999 QSR there was no chapter specifically focusing on beaches. It was stated that there is limited information about the present natural status of beaches and even less about temporal developments. No conclusions on Target implementation and recommendations for management, monitoring and research in relation with beaches were included. This was probably caused by the lack of research programmes on beaches in the Wadden Sea. For the QSR of 2004 data obtained from recent beach ecology studies in Germany, Denmark and The Netherlands was limited, but nevertheless used to describe and evaluate the status of beaches in the Wadden Sea. It was concluded that evaluation of the Target is not possible because of the lack of information about the natural status of beaches in the Wadden Sea. It was recommended that the Target should be reconsidered and the Trilateral Monitoring and Assessment Program be adapted on the basis of advice by an 'Expert Group Beaches'.

There are many different beaches all over the world: rocky beaches with boulders, cobbles or gravel and sandy beaches with coarse to very fine sand. Beaches in the Wadden Sea are sandy beaches with a wide range of grain sizes. This chapter will focus on the ecology of sandy beaches. A beach is defined as the area between low water level and the first dunes on the North Sea side of the Wadden Sea islands. In contrast to studies of rocky shores, the beach ecosystem was largely neglected until Remane (1933) started studies of a sheltered beach on the coast of Germany. Since then, several researchers have started studies on the ecology of sandy beaches in other parts of the world. But until a few years ago beaches in the Wadden Sea were still unknown habitats. This, however, is about to change. Since 1998 researchers in Germany and The Netherlands have made a start with beach ecology studies, which are mainly concentrated on the relation between morphodynamic parameters (e.g. grain size, beach slope, wave energy) and abundance and species diversity of benthic fauna.

9.1.2 Beaches as ecosystems

Short and Wright (1983) describe a number of sandy beach types with different morphodynamic characteristics. Three basic beach types can be identified: reflective, intermediate and dissipative. Reflective beaches are characterized by coarse sediments, a steep beach face, a narrow beach and the absence of a surf zone. Dissipative beaches show fine sediments, a flat beach face, a wide beach and surf zone. Intermediate beaches represent a transition between reflective and dissipative beaches. The morphodynamic characteristics form the basic conditions for the ecological status of the beach. Species diversity and abundance in general show an increase from reflective to dissipative beach state.

Due to the dynamic circumstances the intertidal area of sandy beaches is inhabited by specially adapted invertebrate species. An important group of the interstitial fauna is the meiobenthos, which probably represents a food source available to macrobenthos. The macrobenthic invertebrates, of which some can also be found in the surf zone, play an important role as food for young fish (e.g. sole), shrimp and birds. Birds such as the sanderling, protected under the EC Birds Directive, depend for their food on macrobenthos species that live near the dynamic water line and for the kentish plover and Little tern (red list species) the upper part of beaches is a breeding habitat.

9.1.4 Beaches in the Wadden Sea

Most sandy beaches are situated on the North Sea side of the Wadden Sea islands. In the vegetation typology developed for dunes of the Wadden Sea unvegetated beach plains, beach driftlines and embryonic dunes are distinguished (see chapter 9.2 'Dunes'). Beaches show differences in width, slope, grain size and exposure. This results in differences in invertebrate macro- and meiobenthos species composition and abundance (Mulder, 2000; Menn, 2002; Janssen and Mulder, 2004).

In The Netherlands, beaches range from dissipative to ultra-dissipative. Beaches on the Wadden Sea islands of Schiermonnikoog and Texel are mainly ultra-dissipative, which means that macrobenthos diversity and abundance are relatively high on these beaches compared to beaches of the Dutch shores in the southern part of The Netherlands. There is a clear pattern of zonation of macrobenthic species composition and abundance in the intertidal area of a beach, with maximum diversity and abundance at mid tidal level (MTL) and very few species in low numbers at high water level. The most dominant species on Dutch beaches are the bristle worm *Scolelepis squamata*, the isopod *Eurydice pulchra* and the amphipod *Haustorius arenarius* (Janssen and Mulder, 2004).

In a study by Menn (2002a, b) the effects of eroding and accreting conditions on the food web structure of beaches were determined. The eroding shore (Sylt/Germany) is coarse grained, steeply profiled and receives high wave energy, while the accreting shore (Rømø/Denmark) is fine grained, flat profiled and receives less wave energy. The former resembles dynamic intermediate beach types, and the latter a dissipative beach type (Short and Wright 1983). The study showed that on the eroding, intermediate shore with high wave energy meiobenthos is abundant, while macrobenthos, epibenthic predators, fish and shorebirds are all impoverished. On the accreting, dissipative shore with low wave energy, meiobenthos is also abundant, but with a different species composition. Macrobenthos, epibenthic predators and shorebirds are abundant.

Beaches, however, are not always either reflective or dissipative. Beach character may change with the season as shown for Spiekeroog, which had a reflective beach profile in summer and a dissipative one in winter 1986 (Flemming and Davis (1994). How this dynamic behaviour influences meio- and macrobenthic infauna is not well known.

9.1.5 Human activities and impacts on the Targets

According to the Trilateral Wadden Sea Plan (1997) trilateral policy for beaches takes into account the demands of recreation and tourism, coastal protection and natural values, such as high geomorphological dynamics and important breeding areas. Where possible, the natural situation should be enhanced or restored by 'hands-off management'.

Table 9.1.1: Possible impacts of human activities on the beach Targets.

Activity	Target 1 Increased natural dynamics	Target 2 Favourable conditions for migrating and breeding birds
Beach nourishment	Temporal change in natural dynamics of the beach.	Disturbance of migrating and breeding birds.
Nearshore nourishment	Temporal change in natural dynamics of the nearshore and beach.	Possible food disturbance of migrating and breeding birds.
Hard construction	Definitive loss of natural dynamics of the beach and change in natural dynamics of the nearshore.	
Recreation		Disturbance of migrating and breeding birds.

Activities aimed at coastal protection, such as beach and nearshore nourishment and the building of hard constructions, are necessary to protect the inhabitants on the Wadden Sea islands. To be able to apply Best Environmental Practice, which is mentioned in the Wadden Sea Plan, insight in the possible impacts of these activities on the Targets is needed. These impacts, together with impacts of recreation, are mentioned in Table 9.1.1 'beach nourishments', having relatively short term negative effects on local meio- and macrozoobenthos, can be regarded as an acceptable method for coastal protection, provided that some interval years are kept between successive nourishments to allow for recovery of these infaunal populations (Menn *et al.*, 2003).

Draining of beaches, developed in Denmark as an alternative way of beach protection and applied on the west coast of Jutland (Jakobsen, 2003, 2004) may, however, significantly affect the infauna. These effects have not yet been investigated.

9.1.6 Evaluation of the Targets

There is limited or no information about the natural status of beaches. The Trilateral Monitoring and Assessment Program (TMAP) for beaches and dunes is focused on dune succession and does not provide any information about beaches, neither the natural dynamics of beaches nor favorable conditions for migrating and breeding birds. Therefore, an evaluation of these Targets cannot be made at this moment.

Increasing natural dynamics does not seem to be a good target for beaches because it does not completely describe the natural status of the beach ecosystem, This makes it difficult to determine necessary management measures. Furthermore, natural dynamics of a beach is not a quantifiable parameter, which is an important aspect of a target. Finally, there is no general consensus on the definition of natural dynamics, nor on the methods to describe its status.

9.1.7 Conclusions

Currently, there is no information about the actual status of beaches in the Wadden Sea. TMAP does not provide information about beaches and only very recently were research programs on the ecology of sandy beaches started. An evaluation of the Target can therefore not be made.

Nevertheless, growing human impact 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.

9.1.8 Recommendations

It is recommended to:

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

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9.2 Dunes

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Typical dune landscape with beach plain, embryonic dunes, white dunes, dune grassland, dune heath and dune slacks on the island of Fanø (Photo: J. Petersen).

9.2.1 Introduction

Dunes in the Wadden Sea area are mainly situated on the North Sea side of the islands. These dune ecosystems house typical vegetations which in turn form the habitat of characteristic animals. The West and East Frisian Islands and the Danish Wadden Sea islands are sandy barrier islands with dunes, whereas on the North Frisian Islands only minor parts consist of dunes. Mainly on those parts of the islands, which are exposed to the North Sea, dunes are characteristic landscape elements. Because of their importance for coastal defense, the natural geomorphological patterns have largely been modified and fixed, thereby losing their dynamics.

9.2.1.1 Protection and management

All dunes in the three Wadden Sea countries are under nature protection. Additionally, the large majority of dunes are also protected as nature reserves or national parks and have been designated under the EC Birds and Habitats Directives.

As most dunes on the North Sea side of the islands have a function for coastal defense, management of these dunes is aimed at protecting and maintaining defined parts accordingly. Not all dunes, however, are part of the coastal defense system. In these areas, there is room for natural dune dynamics.

Within the Wadden Sea Plan specific Targets regarding beaches and dunes have been formulated. The Plan further states that the interests of nature protection and sea defense should be harmonized, taking into account the safety of the inhabitants of the islands (Trilateral Wadden Sea Plan, 1997). In continuation of the study of the possible effects of enhanced sea level rise (CPSL, 2001), proposals for future integrated coastal defense and nature protection policies have been developed (CPSL, 2005; see chapter 2.1 'Coastal Defense'), with Best Environmental Practice (BEP) measures and associated integrated policies for a number of sea level rise scenarios (Esbjerg Declaration, 2001, § 75-76).

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.

9.2.1.2 From the 1999 QSR up till now

In the 1999 QSR, it is concluded that 'the status of the dunes has been, and still is, determined by conservative measures of coastal protection' and that 'as a result, there is a relative high percentage of intermediate stages and an underrepresentation of primary and oldest stages'. It is recommended to stimulate natural dynamics 'by abandoning, reducing or modifying coastal protection maintenance works'. It is also recommended to reduce groundwater extractions and to suppress actively some intrusive neophytes such as *Pinus spp.* and *Rosa rugosa*. Monitoring should focus directly on these management issues, es-

Table 9.2.1: Newly developed typology of dune and dune slack vegetation in the Wadden Sea area.

TMAP-type	Dune-types	Vegetation	Natura 2000 habitat types
Xerosere:			
X.0	**Dunes**		
X.1	**Beach plains**	No vegetation	
X.2	**Beach driftline**		
X.2.0	Beach driftline, unspecific		
X.2.1	Cakile maritima type	Cakiletum maritimae	
X.3	**Embryonic dunes**		2110
X.3.0	Embryonic dunes, unspecific		2110
X.3.1	Elymus farctus type	Elymo-Agropyretum, Honkenyo-Agropyretum juncei	2110
X.4	**White dunes**		2120
X.4.0	White dunes, unspecific		2120
X.4.1	Ammophila arenaria type	Elymo-Ammophiletum, Ammocalamagrostis baltica unit	2120
X.5	**Dune grassland**		2130
X.5.0	Dune grassland, unspecific		2130
X.5.1	Corynephorus canescens type (+/- dominant Campylopus introflexus)	Violo-Corynephoretum (+/- Campylopus introflexus), Corynephorion vegetation	2130
X.5.2	Koeleria arenaria type	Tortulo-Phleetum, Phleo-Tortuletum, Festuco-Galietum, Airetum praecocis, Koelerion vegetation	2130
X.5.3	Botrychium lunaria type	Botrychio-Polygaletum, Nardo-Galion vegetation	2130
X.5.4	Carex arenaria type	Carex arenaria unit	2130
X.5.5	Deschampsia flexuosa type	Deschampsia flexuosa unit	2130
X.6	**Dune heath**		mostly 2140
X.6.0	Dune heath, unspecific		mostly 2140
X.6.1	Empetrum nigrum type	Hieracio-Empetretum, Polypodio-Empetretum	2140
X.6.2	Calluna vulgaris type	Hieracio-Empetretum – dom. Calluna vulgaris	2150
X.7	**Dune scrub**		
X.7.0	Dune scrub, unspecific		
X.7.1	Hippophae rhamnoides type	Hippophao-Sambucetum nigrae, Salici arenariae-Hippophaetum	2160
X.7.2	Salix repens agg. type	Dry – fresh Salix repens ssp. argentea (arenaria) and repens ssp. repens vegetation, Pyrolo-Salicetum, Rosa spinosissima-Salix arenaria unit	2170
X.7.3	Rosa canina type	Rhamno-Prunetea vegetation	-
X.7.4	Rosa rugosa type	Rosa rugosa unit	-
X.8	**Dune woodland**		
X.8.0	Dune woodland, unspecific		
X.8.1	Populus tremula type	Populus tremula / Betula pendula / Quercus robur vegetation	2180
X.8.2	Pinus spp. Type	Pinus spp. vegetation	
X.9	**Open dune areas**	No vegetation	mostly 2130
X.10	**Eutrophic dune areas**	Dry vegetation with: Urtica spp., Epilobium angustifolium, etc.	mostly 2130
X.11	**Salty dune areas**	Combination of Xeroserie and Haloserie vegetation	mostly 2130
X.12	**Wandering dunes**		

(Table 9.2.1 cont.)

pecially on particular erosion-sedimentation patterns, exposure to storms, size of the islands, quantities and effects of groundwater extraction and the dispersal of introduced species (Neuhaus and Petersen, 1999)

Since the 1999 QSR, almost all dune areas have been designated under the Birds and Habitats Directives. As a consequence, the quantity and quality of all qualifying habitat types and species should be maintained and reinforced. This means that not only, in accordance with the 1999 QSR, the mere *presence* of all vegetation succession stages (habitat types in Habitats Directives vocabulary) should be guaranteed, but also the presence of their constituents, *i.e.* the characteristic plant and animal species and communities. It is obvious that nowadays these criteria must be explicitly imposed on the target concerning the presence of complete natural dune succession series. Therefore, the evaluation of this target and consequently the monitoring activities must be directed more explicitly to obtaining information about the presence of the whole range of characteristic species and communities as required by the Habitats Directive.

In this chapter, an analysis will be presented of the spatial distribution of major dune types all over the Wadden Sea area, based on a newly developed dune vegetation typology. The results will be evaluated in terms of developments of landscapes, successional stages and species, especially changes in the distribution of rare plants, in-

Table 9.2.1 (cont.)

TMAP-type:	Dune slack types	Vegetation	Natura 2000 habitat types
Hygrosere:			
H.0	**Dune slacks (humid)**		2190
H.1	**Pioneer dune slacks**		
H.1.0	Pioneer dune slacks, unspecific		
H.1.1	Centaurium littorale type	Centaurio-Saginetum	
H.1.2	Radiola linoides type	Cicendietum filiformis, Isoeto-Nanojuncetea vegetation	
H.1.3	Littorella uniflora type	Littorelletea uniflorae vegetation	
H.1.4	Lycopodiella inundata type	Sphagno-Rhynchosporetum, Lycopodio-Rhynchosporetum	
H.2	**Dune slack fens**		
H.2.0	Dune slack fens, unspecific	Juncus spp., Potentilla anserina vegetation etc.	
H.2.1	Carex trinervis type	Caricetum trinervi-nigrae, Caricion nigrae vegetation	
H.2.2	Schoenus nigricans type	Junco baltici-Schoenetum nigricantis, Juncus subnodulosus unit, Caricion davallianae vegetation	
H.2.3	Calamagrostis epigejos type	Calamagrostis epigejos unit	
H.3	**Dune slack heath**		
H.3.0	Dune slack heath, unspecific		
H.3.1	Erica tetralix type	Empetro-Ericetum, Narthecium ossifragum vegetation	
H.3.2	Oxycoccus macrocarpos type	Oxycoccus macrocarpos vegetation	
H.3.3	Molinia caerulea type	Molinia caerulea unit	
H.4	**Dune slack reedbed**		
H.4.0	Dune slack reedbed, unspecific		
H.4.1	Phragmites australis type	Scirpo-Phragmitetum, Schoenoplecto-Phragmitetum, Typho-Phragmitetum	
H.4.2	Carex spp. Type	Magnocaricion units	
H.5	**Dune slack willow shrubbery**		
H.5.0	Dune slack willow shrubbery, unspecific		
H.5.1	Salix cinerea type	Salix cinerea-Salix arenaria unit, Salicetum cinereae – salicetosum repentis	
H.5.2	Myrica gale type	Myricetum galis	
H.6	**Dune slack woodland**		2180
H.6.0	Dune slack woodland, unspecific		
H.6.1	Betula pubescens type	Betula pubescens unit, Empetro-Betuletum carpaticae	
H.6.2	Alnus glutinosa type	Alnus glutinosa unit	
H.7	**Open dune slack areas**	No vegetation	
H.8	**Aquatic vegetation in dune slacks – Hydrosere**	Charetea fragilis, Potamogetoneta, Utricularietea vegetation	
H.9	**Eutrophic dune slack areas**	Humid vegetation with: Epilobium hirsutum, Cirsium vulgare a. arvense etc.	

dicative species and potentially very dominant species such as some grasses, bushes or intrusive neophytes. Attention will be paid to most obvious differences within the Wadden Sea area. Some trends in fauna communities will also be briefly addressed included. Developments in anthropogenic factors supposed to be mainly reponsible for present ecological trends, such as coastal protection, air pollution, groundwater extraction and nature conservation and management, will be briefly evaluated. The chapter wil conclude with conclusions on future dune management and monitoring.

9.2.2. Ecological patterns in the dunes

9.2.2.1 TMAP vegetation typology

A precondition for comparable statements about the situation, problems, nature conservation, management and monitoring of the dunes and dune slack vegetation in the Wadden Sea region is a harmonized typology of all common systems. Such a common dune and dune slack vegetation typology has been developed for this QSR, which can also be used in future assessments of the Trilateral Monitoring and Assessment Program (TMAP).

The 'new' vegetation typology allows the description, recording and comparison of the spatial patterns of all Wadden Sea dunes. The typology is related to the habitats types of the Habitats Directive (HD) and can therefore serve the monitoring and assessment requirements of this directive. Furthermore, it is directly related to the vegetation typology developed for salt marshes (see chapter 7), thus enabling a common analysis of dune, dune slack and salt marsh areas.

To achieve the analysis of the distribution of major dune types, the existing vegetation classifications, as applied in the three countries, and all available and suitable maps have been, as far as possible, translated into the new common vegetation typology.

Table 9.2.1 shows the newly developed typol-

Table 9.2.2: Distribution of dune types in the Wadden Sea (TMAP-types; Natura 2000 types) in percentages per country/ state and island. The vegetation types are arranged in successional order. The last column gives the total area in hectares. The last row gives the percentages per dune type of the total area of the Wadden Sea dunes.

TMAP-type:	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 2002-type:	2110	2120	2130	2140		2160	2170	2180		2190	2190	2190	2190	2190	2190	2190	2180	2190	
								(%)											(ha)
NETHERLANDS	**1.9**	**10.8**	**46.4**	**10.4**	**0.8**	**3.9**	**0.1**	**6.6**	**4.4**	**0.0**	**0.4**	**4.0**	**0.7**	**0.5**	**2.1**	**2.5**	**4.2**	**0.2**	**11313.9**
Texel	0.6	14.3	44.5	9.1	0.5	4.6	0.1	4.8	2.1	0.0	0.3	1.7	1.9	0.4	2.4	3.7	8.8	0.2	2865.8
Vlieland	0.2	6.6	48.5	11.8	1.6	1.3	0.0	23.3	0.0	0.2	0.0	2.4	0.1	1.2	2.6	0.1	0.0	0.0	1262.7
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	**5.3**	**16.5**	**40.2**	**4.4**	**3.2**	**11.3**	**1.5**	**2.5**	**0.6**	**0.2**	**0.7**	**3.6**	**0.9**	**0.2**	**3.5**	**1.3**	**3.2**	**1.0**	**4440.5**
Borkum	10.3	12.8	30.3	1.0	3.6	17.3	0.4	2.7	0.5	0.0	0.9	4.3	1.1	0.1	5.7	1.7	7.1	0.0	1228.6
Juist	1.6	9.0	53.9	3.1	10.1	10.0	0.0	0.0	0.0	2.2	0.9	0.0	3.2	0.0	3.5	2.6	0.0	0.0	436.9
Memmert	15.4	2.8	66.7	0.8	0.2	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.1
Norderney	1.6	21.2	43.8	1.9	0.0	6.6	1.1	2.9	1.5	0.0	0.3	3.5	0.7	0.6	5.4	1.5	4.1	3.2	900.9
Baltrum	1.4	29.8	33.1	0.7	0.8	15.1	1.4	2.3	0.7	0.0	1.9	6.2	0.2	0.0	3.3	2.0	1.1	0.1	248.1
Langeoog	2.9	19.4	28.2	8.7	0.0	14.9	5.9	5.6	0.8	0.0	0.7	7.5	0.0	0.2	1.3	0.5	1.9	1.6	812.5
Spiekeroog	11.3	3.5	63.8	12.4	4.5	3.7	0.0	0.0	0.0	0.0	0.5	0.0	0.1	0.0	0.1	0.1	0.0	0.0	454.3
Wangerooge	0.0	3.2	65.2	10.6	16.2	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.0	0.0	198.8
Mellum	5.8	30.6	61.5	0.0	1.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.9
Minsener Oog	0.0	99.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	82.8
Schleswig-Holstein	**20.3**	**6.5**	**12.6**	**51.6**	**0.0**	**0.0**	**1.0**	**0.3**	**0.0**	**7.6**									**1499.7**
Eiderstedt	0.0	10.7	30.2	24.8	0.0	0.0	1.3	2.7	0.0	30.2									149.0
Föhr	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0									1.0
Amrum	69.0	13.1	2.3	13.8	0.0	0.0	0.0	0.0	0.0	1.8									435.0
Sylt	0.4	2.7	14.7	74.0	0.0	0.0	1.4	0.0	0.0	6.7									914.7
DENMARK	**8.8**	**2.6**	**20.2**	**41.2**	**0.0**	**0.0**	**0.7**	**0.0**	**9.1**	**17.5**									**2645.0**
Römö	13.4	2.5	3.7	47.2	0.0	0.0	0.7	0.0	13.8	18.7									1731.1
Mandö	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0									6.7
Fanö	0.0	0.2	48.2	32.3	0.0	0.0	0.7	0.0	0.0	18.6									746.4
Skallingen	0.2	14.6	64.5	20.7	0.0	0.0	0.0	0.0	0.0	0.0									160.7
WADDEN SEA AREA	**5.0**	**10.6**	**39.0**	**16.2**	**1.2**	**4.7**	**0.6**	**4.3**	**3.9**	**3.0**	**0.4**	**3.1**	**0.6**	**0.3**	**2.0**	**1.7**	**3.1**	**0.3**	**19887.8**

ogy. For the first time it is possible to create an overall picture of the status of the dune ecosystems in the Wadden Sea area. The typology consists of two major sections, *viz.* the **X**erosere (generally: dry dune vegetation types) and the **H**ygrosere (generally: wet dune slack vegetation types) reflecting successional development. The translation to Natura 2000 habitat types (*cf.* Annex 1 of the Habitats Directive) is also included in this table.

9.2.2.2 Distribution of dune types

Data basis

Nowadays, vegetation maps are available of a large part of the Wadden Sea dune areas. The classifications that were being used (von Drachenfels, 2004; Pott, 1995; Schaminée *et al.*, 1995, 1996; Rennwald 2000; Petersen 2000; Petersen and Marencic, 2001) and the unpublished classifications of the Dutch organizations for nature and coastal management Staatsbosbeheer and Rijkswaterstaat) have been brought together in the new TMAP-classification system. As a next step, all available digital vegetation data was compiled in one database. With help of GIS (ArcView), the areas of each dune type could be determined at each preferred scale (per island, country or overall in the Wadden Sea area). The level of detail that could be achieved was dependent on the quality of available data and is mirrored in the assignment of basic units (2 digits after X or H) or of only the main types of the new classification. The results of these analyses are presented in Table 9.2.2 and Figure 9.2.1.

Good quality dune vegetation maps are available for the Dutch islands of Texel (Hartog *et al.*, 1991; Everts and de Vries, 1998a, 1998b; Everts and de Vries, 2000), Vlieland (Brongers and Berg, 1996), Terschelling (Bakker, 1999) and part of Ameland (Bakker, 1998) and for the Niedersachsen islands Borkum (Peters, 1996), Norderney (Hobohm, 1993), Baltrum and Langeoog (Fromke, 1996). The maps of the other part of Ameland (Gutter *et al.*, 1997), Schiermonnikoog (von Asmuth and Tolman, 1996) and the other islands of Niedersachsen (Ringot, 1997) were not made on the level of plant communities or the delimitations of the map units are based on geomorphological distinctions rather than on differences in vegetation composition. However, the map units could still be assigned on the level of basic units, though the reliability will be somewhat reduced. For Schleswig-Holstein and Denmark no complete overview can be given as only data of some xerosere main types and of the hygrosere as a whole is available. For the small Dutch islands Rottumeroog, Rottumerplaat, and Griend (between Harlingen and Terschelling), no detailed vegetation data was available either. On these small islands, beside sand flats and salt marshes, about 200 ha of embryonic (type X.3) and white dunes (type X.4) can be found.

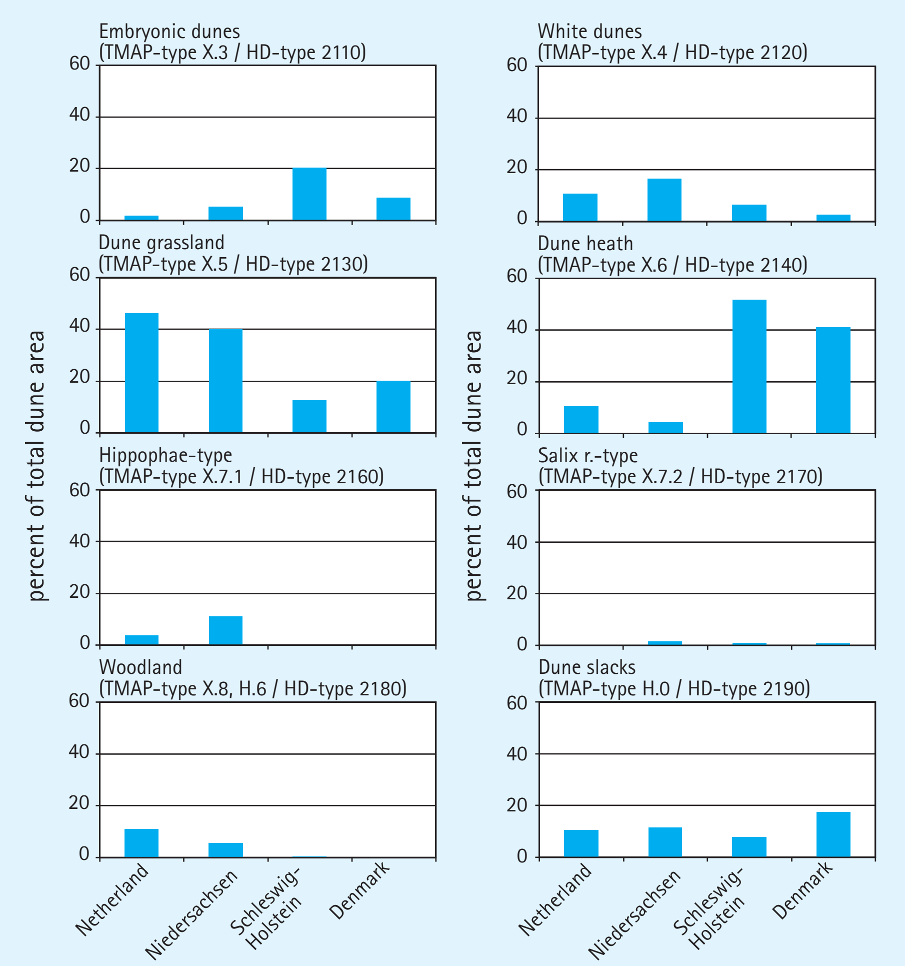

Figure 9.2.1: Relative area (%) of dune types and total area (ha) per country/state.

Dune type distribution

It must be realized that the total dataset contains data originating from 2-12 years ago. Also, comparable datasets from the same area and from different periods are rarely available, as a consequence of which clear trends can not be established with certainty. It must be emphasized that for reliable monitoring repeated mapping in a systematic way is absolutely necessary. The results presented in Table 9.2.2 thus only give a picture of the state of the dunes in the last decade.

The general pattern of dune types of the xerosere consists of mid-successional types dominating pioneer stages as well as dune scrubs and woodland. Overall, grey dunes (X.5-types) cover about 40% of the Wadden Sea dune area. In Schleswig-Holstein (12.5%) and Denmark (20%) their presence is outweighed by the very large area of dune heaths (X.6). Dune heaths cover about 50% of the total dune area in Schleswig-Holstein and about 40% in Denmark). The dune heath area is much smaller in The Netherlands (about 10%) and Niedersachsen (about 5%) and seems to be restricted to only some of the islands.

Both mid-successional dune types, grey dunes and dune heaths, are habitat-types with the indication 'most important areas with high priority' according to the Habitats Directive. In many dunes in the Wadden Sea area, the boreal *Empetrum nigrum*-heath is considered to represent an end-successional stage, because the windy and salty conditions strongly hamper woodland development.

Pioneer dune types usually originate or erode in relatively narrow coastal zones which, by definition, on a large island cover proportionally much smaller areas than on a small island. This will be the main cause of the low coverage (2%) of embryonic dunes (X.3) on the large Dutch islands in comparison to the higher cover (5-20%) of this type on the smaller islands elsewhere in the Wadden Sea area. The presence of white dunes (X.4) shows very large differences between dune areas. No clear general trend can be observed.

The observation made in the 1999 QSR with regard to the distribution of white dunes cannot be compared with the recent results because of the different quality of the data. The recent cal-

Liparis loeselii, the priority Natura 2000 habitat species is typical for basiphilous pioneer vegetation of dune slacks (Petersen, 2000) (Photo: J. Petersen).

culation is based on a more detailed (GIS data) and complete data set and hence gives more reliable information.

The occurrences of both pioneer types of the xerosere (X.3 and X.4) indicate 'most important areas' in terms of the Habitats Directive.

The dune scrubs (X.7), a mid-successional stage, cover a larger area in Niedersachsen (16%) than in The Netherlands (5%). On the Niedersachsen islands especially *Hippophae* bushes (X.7.1) occur frequently. They are to be found mainly in small zones at the inner side of white dunes stabilizing sandy soils which still contain small quantities of lime. This lime dependence is also the reason that type X.7 can hardly be found on the 'lime-poor' northern islands (Petersen, 2000). The lime-containing zones with *Hippophae rhamnoides* occupy smaller proportions of dune area on the large Dutch islands, similarly as embryonic dunes.

The high percentage of dune woodland in The Netherlands (11%) can be ascribed to the large pine plantations (X.8.2) since the beginning of the 20th century. Part of these plantations have been reformed to deciduous or mixed forests (indicated as X.8). For Schleswig-Holstein and Denmark no estimates of the coverage of these types could be made. On Rømø and Fanø, however, also a considerable area is covered with pine plantations.

In the Habitats Directive, areas with dune scrubs are considered 'most important areas'. Most of the types of dune woodland from the xerosere in the Wadden Sea dune areas, those having their origin in pine plantations or presently still being in a relatively early successional stage, have no special status in the Habitats Directive. Only the small patches with indigenous dune woodland types (X.8.1 and H.6) can be considered 'most important areas'.

The hygrosere types (H-types) cover about 15% of the dune area over the entire Wadden Sea area. On the small uninhabited islands, however, they are completely absent, while the island Spiekeroog has only very few dune slacks. The low values for Wangerooge are based on wrong mapping. For Schleswig-Holstein and Denmark, a detailed picture of the distribution of the individual dune slack types cannot be given because of insufficient data.

Only about 0.5% of the total dune area of Niedersachsen and The Netherlands is covered with pioneer dune slacks (H.1). Only 4-5% is covered with dune slack fens (H.2), and less than 0.5% is covered with wet heathland (H.3) which is probably underestimated because of its frequent occurrence in complexes with X.6 dry dune heathland. Various other types all have low percentages: reedbeds (H.4: 2.5%), willow shrubbery (H.5: 2%) and birch and alder woodland (H.6: 3.5%).

Of the dune slack fens, only a small part harbours species-rich *Caricion davallianae* vegetation (H.2.2) with many red list species such as *Liparis loeselii*, which is specifically mentioned as one of the very rare high priority species in the Habitats Directive. The occurrence of all dune slack types indicates 'most important areas' in terms of the Habitats Directive.

9.2.2.3 Fauna of dunes

The Wadden Sea dunes qualify for the Birds Directive especially as breeding habitat for a number of bird species. Characteristic species breeding in dunes are the common eider (*Somateria mollissima*), hen harrier (*Circus cyaneus*), Eurasian curlew (*Numenius arquata*), herring gull (*Larus argentatus*), lesser black-backed gull (*Larus fuscus*), short-eared owl (*Asio flammeus*) and passerines such as wheatear (*Oenanthe oenanthe*) and red-backed shrike (*Lanius collurio*). In addition, primary dunes and beaches are breeding habitats for the kentish plover (*Charadrius alexandrinus*), great ringed plover (*Charadrius hiaticula*) and little tern (*Sterna albifons*), for which natural dynamics in habitat are of prime importance (see chapter 12.1 'Breeding Birds').

In The Netherlands and Niedersachsen, populations of hen harrier and short-eared owl have their core breeding areas at the Wadden Sea islands, but show opposite trends. Both species are increasing in Niedersachsen and declining in The Netherlands. This decline has often been attributed to the increase of scrub vegetation (as a result of increased atmospheric deposition), which hampers both species' hunting techniques since visibility of main prey like voles deteriorates. However, declines in these species might also be related to decreased populations of rabbits (*Oryctolagus cuniculus*), which are also taken as prey and have recently suffered declines due to the virus desease VHS. Another factor influencing the decline in hen harriers might be the locally increased area of reedbeds and scrub which has facilitated breeding for marsh harriers (*Circus aeruginosus*) and has increased competition for nest sites and food. Currently, a research project is carried out to study the downward trend of the hen harrier in more detail.

Other qualifying species of the Birds Directive are faced with sharp declines as well, *e.g.* wheatear and red-backed shrike. Recent research showed clear relationships between the occurrence of red-backed shrikes and decreased availability of prey, which in optimal conditions comprises a large variety of insect species (Esselink *et al.*, 2001). It was found that in open dune areas with grass-dominated vegetation stands and hardly any flowering plants, insect diversity was much lower compared to dune areas with a more varied vegetation. Amphibians and reptiles also occur in higher densities when vegetation is less uniform and therefore contribute to the prey availability for shrikes.

The increase of the relatively monotonous grass dominated grey dunes at the expense of the much more varied and species-rich vegetation from earlier days thus leads to a serious decrease in ornithological values in the Wadden Sea dunes. In addition, some of the changes in vegetation are related to changes in mammal densities such as the large decline in numbers of rabbits (see above). This development has caused a reduction in nesting opportunities for, for example, the wheatear and also contributes to the expansion of higher vegetation through lack of grazing by rabbits. As a result, short-vegetation areas, preferred by nesting wheatear as well as hunting raptors such as hen harriers have become scarce.

9.2.2.4 Development of dominant plant species and neophytes

The grey dunes of the xerosere (X.5) and the dune slack fens (H.2) of the hygrosere are very diversified. Their subtypes show large differences in biodiversity and presence of Red List species. In this respect the *Koeleria arenaria* type (X.5.2), the *Botrychium lunaria* type (X.5.3) and the *Schoenus nigricans* type (H.2.2) show the highest nature conservation value (Petersen, 2000; Peppler-Liesbach and Petersen, 2001). At the same time, these relatively early and nutrient poor successional types occupy only a very small part of the dune area, in an absolute as well as a relative sense. The same is true for pioneer dune slacks (H.1) and dune slack heaths (H.3). Monotonous vegetation stands with very few or only one dominant grass species are far more abundant, *e.g.* dense *Carex arenaria* vegetation often together with *Ammophila arenaria* (X.5.4) in dry circumstances and *Calamagrostis epigejos* stands (H.2.3) in wet but sometimes also fairly dry conditions.

The intrusion of dominating grass species may be considered a stage in natural succession. The general impression, however, is that this process has been strongly accelerated by anthropogenic influences, such as the intensive substrate fixation during the last century for coastal protection purposes, or just to avoid sand blowing. Increased atmospheric deposition for some decades (now decreasing again) and the lowering of groundwater tables by increasing groundwater extraction or artificial drainage have also contributed to an accelerated succession. These influences will be treated in section 9.2.3. The extent to which the replacement of low productive (plant and animal) communities by high productive communities has been accelerated artificially can only be clarified when there is a good picture of the lifespan of each successional stage. Theoretically, in an equilibirum situation between erosion, accretion and stabilization, the lifespan of all stages should be mirrored in the areas occupied by those stages. Here lie promising opportunities to approach natural references for dune type patterns in dune sys-

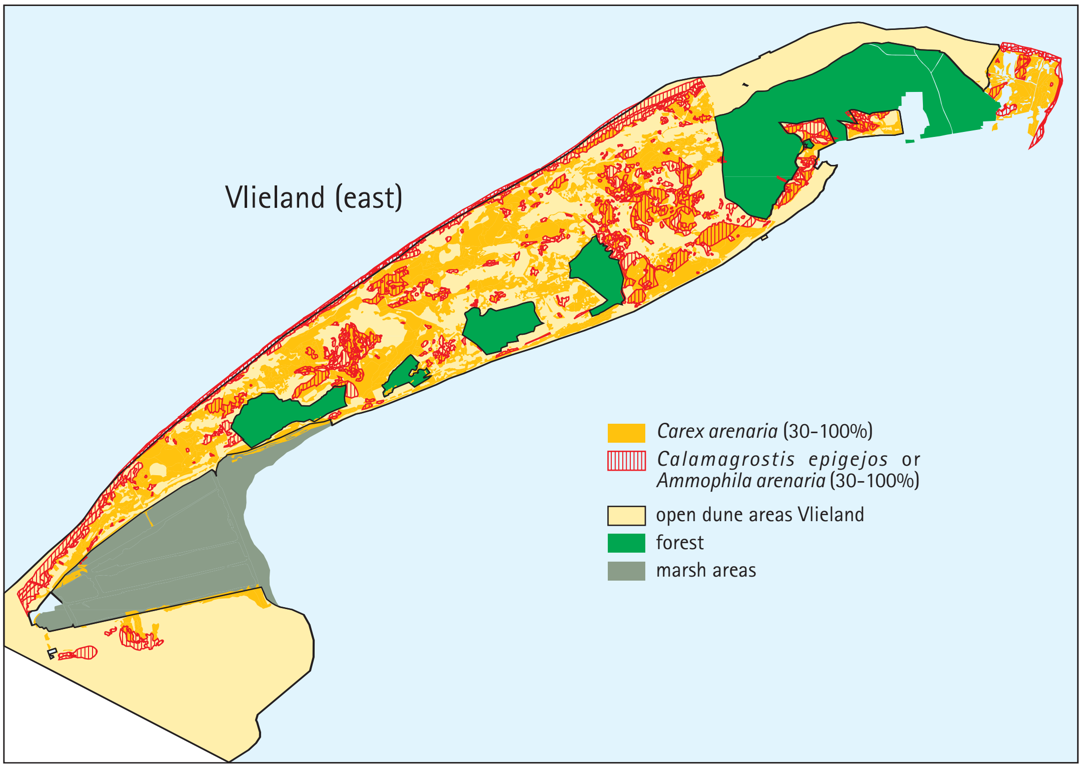

Figure 9.2.2: East part of the island of Vlieland (The Netherlands). Presence of vegetation types dominated by one or a few species according to the vegetation map of 1996 (Brongers and Berg, 1996). The marsh area in the west and beaches and forests were not mapped.

tems at given spatial and temporal scales. The lifespan of the stages and the manageable spatial and temporal scales are important research topics as a basis for future dune management.

The situation on the island of Vlieland (Figure 9.2.2) exemplifies the recent dominance of grass species and *Carex arenaria* as occurring in almost all Wadden Sea dune areas. At the beginning of the 20th century, Vlieland consisted of blowing sand and almost nothing else. In less than a century, this very dynamic situation changed to an almost completely stabilized soil. Active stabilization will first have stimulated a scattered establishment of grass species, which in a later stage, under conditions of increased atmospheric nutrient input, led to the development of dominant communities consisting of one or two species. This process can be deduced from the observations by Gerlach *et al.*, (1994) and Veer (1997) that in grass-dominated plots mineralization largely exceeds atmospheric nitrogen-input, while this is not the case in open dune vegetation Atmospheric deposition, in this view, triggers grass-encroachment, which subsequently is enhanced by positive feedback mechanisms caused by increasing nitrogen mineralization.

Though not much is known in detail about this type of feedback and facilitation mechanisms, it is likely that comparable processes play a role when neophytic species 'suddenly' come to dominance. The moss species *Campylopus introflexus* can become dominant very fast in areas with a short and often sparse vegetation, such as the *Corynephorus canescens* (X.5.1) type (*cf.* Ketner-Oostra and Sýkora, 2004; Hahn, 2005). *Rosa rugosa* shows similar behaviour in dune grasslands (type X.5) and *Hippophae* bushes (type X.7.1) often near or within human settlements. Hahn (2005) gives a picture of the present abundant distribution of both species on the islands of Niedersachsen (Figure 9.2.3). A neophytic plant species, which in the near future may become a dominant species in the dunes, is *Senecio inaequidens*. Such intrusions of neophytes seem to occur when anthropogenic influences create 'new' niches (open and slightly eutrophicated) where 'new' species accidentally fit in very well.

Pinus species have dispersed considerably along the borders of the original plantations. *Prunus serotina* spreads in a more scattered pattern everywhere in the dunes where vegetation succession proceeds by accumulating organic matter. These neophytic trees appear to replace indigenous trees during bush encroachment and early stages of forest development.

The cranberry (*Oxycoccus macrocarpos*), also a neophyte, occurs very frequently on some of the Dutch Wadden Sea islands. A commercial cranberry-culture exists on Terschelling. The berries are harvested and processed by a few professional enterprises which lease dune slacks where the species is abundant. The cranberry reaches dominance in older successional stages of dune slacks where once the species-rich *Schoenus nigricans* type (H.2.2) was present and now has lost its vitality. The cranberry may intrude and compete with *Carex trinervis* type (H.2.1) and the *Erica tetralix* type (H.3.1), conquering them in permanent wet circumstances. The species itself will in turn be conquered by *Calamagrostis epigejos* or *Phragmites australis*. Locally, on Terschelling, some old dune slacks are specifically managed for cranberries by removing succeeding species mechanically and maintaining a high water level by irrigation.

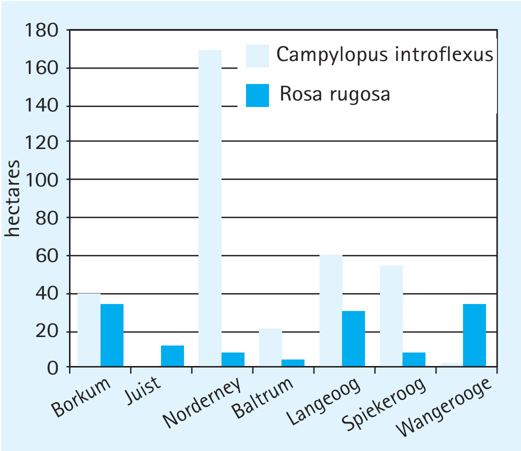

Figure 9.2.3: Occurrence (ha) of neophytes on the islands of Niedersachsen (Hahn, 2005).

9.2.3. Anthropogenic activities as causes of ecological change

9.2.3.1 Coastal protection

In chapter 2.1 'Coastal defense', an overview is given of the status quo of coastal protection and the different policies and strategies applied in the Wadden Sea area. In the following, some remarks will be made about the measures taken or planned for the sandy coast and their consequences for natural dynamics in the Wadden Sea dune areas.

There is a common trend for the application of more natural methods of coastal protection in all three countries (chapter 2.1). A shift has occurred from dune reinforcement to beach and shoreface nourishment. In Niedersachsen, however, rear side dune reinforcements are executed if necessary and sand trapping measures, *e.g.* planting of marram grass, are still carried out on a regular basis. This is not the case any more along the Wadden Sea dune coast in The Netherlands, except for some short trajectories where houses or other buildings could be overblown.

Where such a shift in coastal conservation methods is realized, this may favor sand accretion in an almost natural way. This may lead to the building up of new dune systems in which natural succession can start again. An impressive example of this can nowadays be seen on Schiermonnikoog where since around 10 years ago, small dunes, brackish sandy plains and completely fresh dune slacks with characteristic plant communities have gradually developed on the North Sea beach along a trajectory of 5-10 km.

It must be realized, however, that this is a typical development for a coastline extending either by natural processes or by nourishment methods. The massive remains of the former sand dikes still prevent the formation of natural dunes and dune slacks on the coastal plains behind the beach. The densely vegetated and heavy sand dikes, in which very large quantities of sand are immobilized, will obstruct natural dune formation for a long period.

So, there are still many uncertainties. Therefore, structural information flow and intensive research are needed, also with respect to the expected sea level rise and the possible bottom subsidence due to exploitation of natural gas from fields under or near the Wadden Sea. A few important themes are:

- What is the relationship between different sea defense strategies along the North Sea coastline of the Wadden Sea and the occurrence of young successional stages of dunes?
- Where sand nourishment is adopted as a long-term strategy to be applied always at the same spots, coastal *erosion* will be very restricted and probably also the concordant periodical degeneration of older successional dune stages. Can, under such conditions, young successional stages redevelop periodically or will such a coastal protection strategy lead to a convergence to grey and brown dune types on the long term?
- It is not clear how to deal with the troublesome results of previous stabilizing methods when aiming at a more dynamic dune system. A closely vegetated and massive sand dike on Schiermonnikoog appeared to suddenly stop the development of pioneer vegetation in fresh-water fed young dune slacks (Grootjans *et al.*, 1999). To restore the necessary dynamics, the sand dike should be removed completely. On Terschelling the artificial stimulation of inward sand blowing from a huge sand dike appears to lead to the development of dry pioneer vegetation and locally also of pioneer species in wet conditions. The question to be

> answered on a trilateral level is: what measures should be taken in different situations to deal with the presence of huge sand dikes, when dynamic processes are to be stimulated?

This exchange of information should be accompanied by projects focusing on the development of methods which stimulate the (cyclic) establishment and further development of pioneer stages by initiating or influencing geomorphological processes.

9.2.3.2 Atmospheric deposition

Atmospheric deposition of nitrogen is supposed to have contributed to an accelerated succession in the dunes of the Wadden Sea islands, especially in the nutrient poor types of dry dune grassland (TMAP-types X.5.1, X.5.2 and X.5.3), dune heaths (X.6.1 and X.6.2) and pioneer dune slacks (TMAP-types H.1 and H.2.2). Depositions of 10 - 15 kg/ha of nitrogen are considered to be critical loads above which *Corynephorus canescens* vegetation, *Schoenus nigricans* communities, etc. rapidly transform to dense species poor grass stands. Most probably, depositions above this critical load have triggered grass encroachment in large parts of the dry dune areas (cf. par. 9.2.2.4.).

On the mainland the deposition of nitrogen has considerably increased during the last century but declined again since beginning of the 1990s. The Netherlands Environmental Assessment Agency (RIVM, 2004) gives the following average figures for The Netherlands: total N-deposition (wet and dry) rose from 10 kg/ha/yr in the 1950s to about 40 kg/ha/yr in the 1980s and decreased again to 27 kg/ha/yr in 2002.

In chapter 5 'Eutrophication' an average N-deposition of 17 kg/ha/yr is assumed for the whole Wadden Sea area. The background level of N-deposition in the Wadden Sea has always been lower than on the mainland because of the larger distance of the main emission sources. The trends of N-deposition during the last decades were however comparable to those on the mainland. Extrapolating this trend to the near future gives a predicted development of N-deposition for the Dutch Wadden Sea islands as presented in Figure 9.2.4.

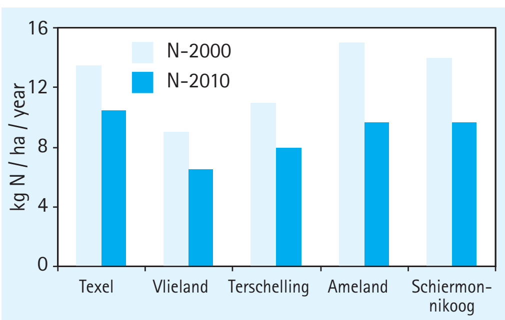

Figure 9.2.4: Nitrogen deposition on the Wadden Sea islands in 2000 and 2010 (from Buijsman, 2003).

These trends will have positive effects on vegetation development, especially when it is realized that part of the deposition has a very local character, which implies that there is considerable variation around an average background level of nitrogen deposition. On Vlieland for example, where there are no farms and hardly any agricultural activities, the deposition is considerably lower than on the other islands. Here, local peaks occur closest to agricultural activities where ammonium is emitted, *i.e.* near the inner dune fringes. The majority of most sensitive pioneer stages are, however, located in the central and outer dune areas.

It can be concluded that in the second half of the 20th century atmospheric deposition surpassed the critical load of some sensitive dune vegetation types (Sival and Strijkstra-Kalk, 1999). This has led to a rapid grass encroachment in large areas and in some places to a dominance of neophytic species. Despite its recent decline, N-deposition may still lead to eutrophication at a few locations. However, the largest problem of N-deposition nowadays is that it has initiated a self-enhancing process in specific habitats. Now that nitrogen deposition has fallen back to a lower level and is expected to decline further in the near future, these habitats do not automatically renew themselves. Standing crop and litter layers in closed stands of grass species and bushes will have to be removed to enable the re-establishment of the original vegetation. Executing these kind of measures presupposes that N-deposition at the selected locations is, once and for all, below the critical load which is given for the projected vegetation development. Thus it is important to obtain on a trilateral level a good picture of the local spatial patterns of remaining N-deposition.

9.2.3.3 Groundwater extraction

In the 1950s, when more and more tourists started to visit the Wadden Sea islands resulting in a growing need for drinking water, a start was made with the construction of groundwater pumping stations on several islands, almost at the same time. Figure 9.2.5 shows that on all islands the quantities of groundwater extracted increased very fast, in fact up till the mid 1980s. For the islands of Schleswig-Holstein no data is supplied. For the Danish islands, only data for the groundwater withdrawals in 2003 is available.

Since around 1980 the negative consequences of groundwater extraction for the ecological val-

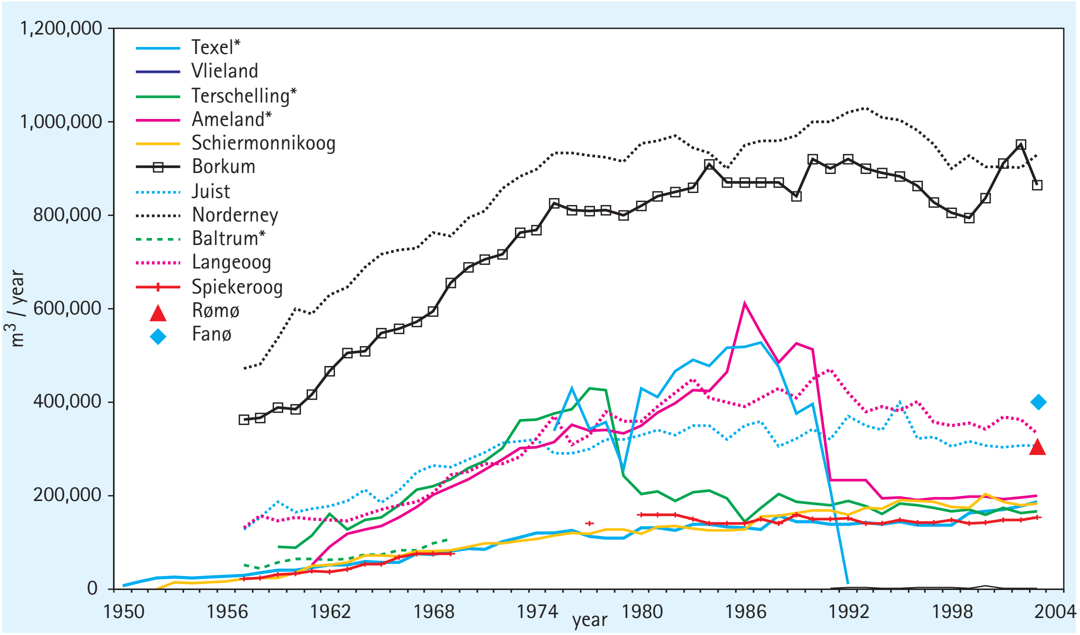

Figure 9.2.5: Groundwater extractions on the Wadden Sea islands (in m³/year); asterisks indicate islands which now are totally or partly provided with drinking water from the mainland.

ues in the dune slacks were recognized as being mainly a result of developments in biological and hydrological sciences in The Netherlands. This led to a new scientific discipline called ecohydrology or hydro-ecology. More and more serious consequences for pioneer dune slacks became clear (Bakker *et al.*, 1979), even when those influences on hydrology were so small that no physical drought for plants could be demonstrated in any season (Grootjans *et al.*, 1988; Lammerts *et al.*, 1992). The characteristic plant communities of the dune slack types H.1.2, H.1.3 and H.2.2 have been shown to depend on the presence of a pH-buffer system which is operated by soil-water relationships (Lammerts, 1999; Petersen, 2000). Especially in older dune systems the stability of such relationships is often determined by groundwater flow systems of different scales. When human influences interfere with groundwater flow patterns this leads to chain reactions which eventually result in the degradation of the dune slack communities with many red list species. Grootjans *et al.* (1996) made this very clear in their study on the effects of the groundwater extraction on Schiermonnikoog on a dune slack which once had a very well developed *Schoenus nigricans* vegetation (type H.2.2).

When, in the 1980s, the water companies on the Dutch islands were urged to supply more water to meet the increasing demand from increasing tourism, they needed formal authorization from provincial officials. Being familiar with the above scientific developments, these officials required serious research into the possible ecological consequences of increasing groundwater withdrawals. Around 1990, many research projects, consisting of hydrological modeling, geochemical analyses and vegetation studies, were executed in the potential sphere of influence of groundwater extractions. Not only were actual effects of groundwater extraction established (and often even more of other hydrological interferences), serious effects of increasing extractions were also predicted. These results prompted several of the water companies to change their strategies concerning the supply of drinking water.

In 1979, Terschelling was the first to replace a large part of the dune water extraction by water supply from the mainland via transport pipes across the Wadden Sea. Ameland followed this example in 1999. On both islands groundwater extraction was continued but at a much lower and up till now constant level below 200,000 m³/year. Since 1988, Texel has also obtained its water from the mainland, and the groundwater extraction has been gradually reduced to zero in 1993.

The smaller islands of Schiermonnikoog and Vlieland kept their own groundwater extractions (about 180,000 m³/year). Instead of building pipelines, on these islands integral water management projects where executed in the early 1990s to develop strategies for minimization of ecological effects. Integral solutions were found in introducing methods to reduce water use, in adopting new methods of extraction and in spreading extraction locations vertically (in different layers) and horizontally in such a way that hydrological regimes at sensitive locations were not or only minimally influenced. On both islands vegetation developments and hydrological regimes are monitored in dune slacks which may still be influenced.

Right from the start in the 1950s, the islands of Borkum and Norderney in Niedersachsen extracted much larger quantities of groundwater than the other islands because of the much larger numbers of tourists. Both islands now withdraw about 900,000 m^3/year. The much smaller islands of Wangerooge and Baltrum, on the other hand, have a water supply from the mainland. There are still considerable groundwater withdrawals on Langeoog (about 350,000 m^3/year) and Juist (about 300,000 m^3/year) and a relatively small extraction on Spiekeroog (about 150,000 m^3/year).

In view of the fact that tourists and dune slack vegetation both need groundwater, the interdisciplinary research project 'Sustainable groundwater management in hydrogeological and ecological sensitive areas of the North Sea Coast' (Petersen *et al.*, 2003) was carried out in Niedersachsen. In this project standard values for a sustainable groundwater management were developed by assigning groundwater dependent vegetation units to moisture classes and associated groundwater levels. The resulting data set proved to be a reliable foundation for monitoring systems and scenario studies (Petersen *et al.,* 2001, 2003; Petersen and Sütering, 2003). It enables the evaluation of the effects of groundwater extractions (present or planned) and other hydrological measures on vegetation types. Additionally, the introduced method fulfils the demands of the EC Water Framework Directive to evaluate groundwater-dependent biotopes. The method is presently applied in bio-monitoring projects on the islands of Norderney and Langeoog, designed to periodically control the effects of groundwater extraction. When bio-monitoring indicates that ecological effects are likely to become serious, the extraction methods are adjusted in a way so as to minimize the ecological effects, *e.g.* by using other groundwater sources or extracting in other time periods. Water-supply companies on Norderney and Langeoog have shown that this can be done without affecting the water supply. On Borkum, however, very sensitive areas with recent wet dune slack vegetation (H.1.2, H.1.3, H.2.1, H.2.2) are currently still largely affected by the huge groundwater extraction (*cf.* Fig. 9.2,5) No adequate management measures or bio-monitoring are carried out there, though the positive examples of Norderney and Langeoog could easily be applied in other areas.

In relation to the large drinking water extractions on the above islands it must be realized that the fresh water reservoirs of all Wadden Sea Islands are relatively small. With an ever increasing number of tourists, many islands will not be able to supply enough drinking water from that reservoir without damaging fresh water dune slacks, not even when extraction methods are adjusted based on the results of bio-monitoring. At some point in the future, groundwater abstraction will become a threat to future dune slack development, unless expensive deep-infiltration techniques will be applied, in which purified surface water is being stored in the deep subsoil (van Dijk and Grootjans, 1993).

In 2003 considerable quantities of groundwater were extracted on the Danish islands of Rømø (399,000 m^3) and Fanø (302,000 m^3), on the latter island not only for drinking water but also for irrigation of agricultural grounds. Neither for the Danish nor for the Schleswig-Holstein islands is any information available on the possible effects of groundwater withdrawal on sensitive dune slack vegetation.

It can be concluded that within the Wadden Sea area there are large regional differences in the role of groundwater extractions as a cause of degradation of dune slack vegetation. This is typically a matter that needs to be attended to on the trilateral level. Priority should be given to:

- organizing exchange of information and knowledge between all regions,
- assessing the state of the art on the Schleswig-Holstein and Danish islands,
- ecologically optimizing the extraction methods (and location choices) on all islands, including the introduction of appropriate management schemes based on bio-monitoring (combined monitoring of vegetation and hydrology).

9.2.3.4 Nature Management

Proper management of dune and dune slack areas in the Wadden Sea, whether national or trilateral, can preserve or even increase the typical dune vegetation with their diversity of plants and animals. For the sake of preserving biodiversity, nature conservation organizations more and more apply management measures such as sod-cutting, mowing and cattle-grazing (Grootjans *et al.*, 2002; Petersen and Westhoff 2001; Petersen, 2000, 2000a, 2001, 2004). The intention is to maintain or restore species-rich ecosytems (*e.g.* nutrient poor dune grasslands), ecotopes with red list species (*e.g.* young dune slacks) or specific biotopes for rare species (*e.g.* reedbeds for birds such as bitterns and marsh harriers and bare or scarcely

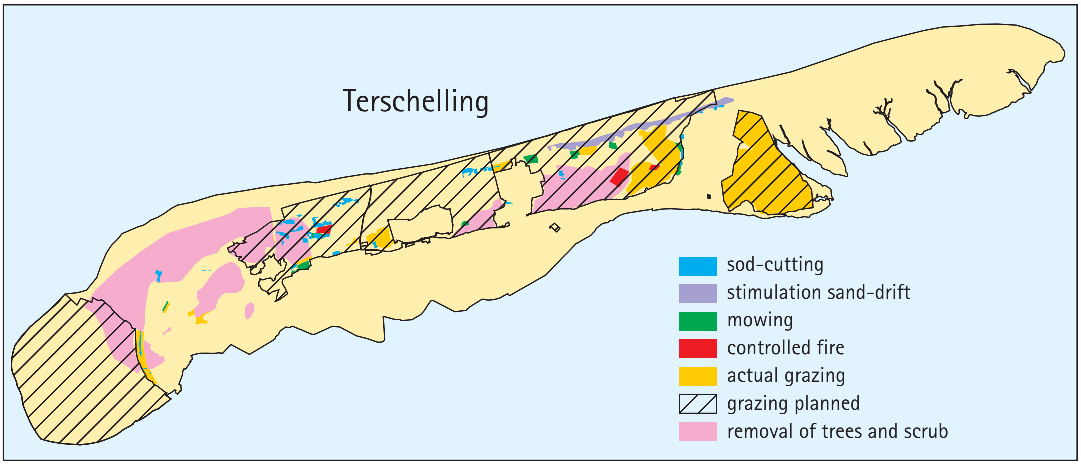

Figure 9.2.6: Nature management measures in the Terschelling dune area. Sod-cutting and stimulating sand-drift were executed in the last 2 decades, controlled fire management was carried out in 2003 and the other activities are permanent or regular. The extension of cattle-grazing areas is planned to happen in the next decade.

overgrown muddy sites for avocets, plovers and sandpipers). This implies that natural succession is set back, fixed in its current state or, at least temporarily, temporized. Such management strategies are accounted for by stating that it is human influence itself which did and does accelerate succession by geomorphological stabilization, atmospheric deposition and interfering with hydrological regimes (as illustrated in the foregoing paragraphs). In addition, until the beginning of the 20th century the dunes have been used very intensively by farmers and other island inhabitants. They needed everything which nature had to offer for their very existence. So they gathered marram grass for roofing, felled wood and cut turfs and other sods as fuel, picked cranberries and other fruits, and used the dunes especially to feed their livestock. All these activities made the dunes very dynamic in the early days (van Dieren, 1934). Consequently the authorities prohibited or restricted many activities for reasons of coastal defense and to prevent huge loads of sand blowing over houses or complete villages. Later on, the inhabitants of the islands did not need the dunes anymore as direct means of existence. As a consequence anthropogenic as well as natural stabilization of dune areas gradually started to predominate. Nowadays many of the traditional activities are used again as nature management methods, though applied in a more systematic way and at sites where the perspectives for maximal biodiversity are greatest. The most important management methods are

- sod-cutting to create secondary pioneer sites, mostly applied in wet dune slacks where plant communities of open water (H.8 types: Potamogetonetea, Charetea) or periodically inundated bare sand soils (H.1 types: Littorelletea, Isoeto-Nanojunceta or H.2.2 type Caricion davallianae) can establish,
- chopping and removing standing crop and litter layers, using machinery especially designed for this purpose; up till now successfully applied in dry and humid dune heaths, especially on Texel,
- mowing, yearly in August/September; often applied in species-rich grasslands with Nardo-Galion or Calthion vegetation but also in dune slacks with Caricion davallianae elements,
- controlled fire-management, mostly in dune heath land where it appears to be rather successful especially when it is combined with other management methods such as grazing, especially on Fanø,
- grazing, more and more applied in large areas including a broad variety of ecotopes; cows, horses, sheep and goats are used in almost all possible combinations; sometimes grazing is applied only in or immediately after the growing season, sometimes year-round.

Figure 9.2.6 gives a picture of the actual management practices on Terschelling. For the whole Wadden Sea area only a rough picture can be given. Active measures seem to be an integral part of management practice in the Dutch areas. On the German islands conservation generally implies that no regular, periodical measures are applied. Recently, however, some nature management projects have been started on Borkum and Langeoog. On Rømø and Fanø some dune areas have been cleared by sod-cutting, others are grazed and a few hectares have been burnt. It may be concluded that there are differences in management strategies between the three countries, probably as a consequence of traditional differences in nature conservation approaches. On this subject more communication and exchange of views seems to be necessary. This may contribute to a better-focused realization of the trilateral Targets, though a similar approach in each of the countries is not necessarily preliminary for a most optimal result.

9.2.4. Evaluation of the Targets

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

1. Natural dynamics have increased at the non-inhabitated 'heads' and 'tails' of the islands because coastal protection has recently been stopped almost everywhere along these trajectories. As a consequence areas with dry and wet pioneer stages have expanded here.
2. Along the central parts of the islands the area of dynamic dunes has also increased somewhat because only at some locations were sand dikes still maintained and sand nourishment has taken place. However, the area with embryonic dunes (X.3), white dunes (X.5) and primary dune slacks (H.1) still is very limited. The characteristic hard elements and substantial, densely vegetated sand dikes remaining from previous coastal management appear to restrict dynamic processes to a large extent. Only very locally have some experiments been carried out to stimulate sand blowing.
3. Because of lacking data for some of the types and some regions a conclusive overview of dynamic processes is still lacking. This is also due to some definition issues, *e.g.* dense grass vegetation, especially of *Ammophila arenaria*, can occur in white dunes as well as, nowadays, in grey dunes and these dune types have not always, or at least not always in the same way, been properly distinguished in the original vegetation surveys.

An increased presence of a complete natural vegetation succession.

4. About 2/3 of the Wadden Sea dune area consists of mid-successional types (X.5, X.6, H.2, H.3 and H.4). Large parts of the areas, allocated as such, are eutrophicated and covered with dense grass vegetation. As a consequence the more open and species-rich grey dunes (grasslands and dune heaths, the most important types with highest priority according to the Habitats Directive), and secondary pioneer vegetation have further declined. Diversity of flora and fauna in the central open dune areas on the islands decreased accordingly.
5. Not only pioneer stages but also natural scrub and woodland vegetation cover only a minor part of the total dune area. This may have to

About natural and anthropogenic dynamics

In the 1999 QSR, chapter 5.14, 'rise, stagnation and regression of the sea level' are said basically to be main factors triggering natural dynamics in dune areas. They do so by making the coastline move forward or backward. This means that the actual state, direction and speed of natural succession of a dune area depend on its stage and position in the spatio-temporal cycle of interchanging erosion and accretion regimes in the bordering coastal zone. 'Thus', according to the 1999 QSR, 'the nature of rarity (of dune types, communities, species) is, when left in the hands of natural dynamics, dynamic itself and species *etc.* may become extinct locally but not in the whole variety of dune sites'. Anthropogenic influences are supposed to imbalance this type of locally and periodically occurring rarity. Therefore these influences should be reduced or compensated for.

However, because human beings lived on the islands and harvested from nature through a vast variety of 'farming' activities long before any ecologist described landscape and vegetation, there cannot be a definite statement about the nature of a *natural* equilibrium between coming and going species in such a landscape. At least such a statement cannot be based on historical references alone. Keeping this in mind the trilateral targets can, for the time being, only be operationalized in a opportunistic rather than in a philosophical way. This means that natural dynamics should be stimulated where they are severely suppressed by human influence and where this suppression leads to decreasing biodiversity mostly by lacking pioneer stages with characteristic and rare dune species, causing at the same time a domination of intermediate successional stages. Favoring valuable early successional stages above older species poor stages may, in this perspective, also be realized by the application of active measures comparable to the former agricultural uses or derived from it, such as sod-cutting, mowing, grazing and controlled fire management. Such activities can be considered a compensation for lacking natural dynamics as well as being in accordance with historical practices.

Typical primary dune slack (Petersen, 2000) (Photo: J. Petersen).

do with bad conditions for natural woodland development in areas with intensive grass encroachment but also with the fact that the Wadden Sea dunes are still relatively young.

6. Atmospheric nitrogen deposition, supposed to be one of the important factors responsible for the 'sudden' grass and bush encroachments in the dunes, has been declining again since the beginning 1990s. It is expected that only near local sources will this remain a problem in the future. The largest problem nowadays is the remaining high standing crop and thick litter layers which do not allow a further natural succession very easily.
7. Since the 1960s, human interferences with natural hydrological systems, especially groundwater extractions, have led to a degradation of species-rich dune slack communities and an accelerated succession to drier and often more nutrient-rich communities. Nowadays there are large regional differences in the magnitude of these extractions and in the extent to which measures have been taken to prevent damage to natural dune vegetation. In The Netherlands a great deal of research has been done and many measures have been taken, and at present water withdrawal no longer has any large impact on dune slacks. In Niedersachsen, as a result of an interdisciplinary research project, sustainable groundwater management was implemented with considerable success on Norderney and Langeoog by the water supply companies. However, in other sensitive areas, such as on Borkum, such bio-monitoring-based management is urgently required. In Schleswig-Holstein and Denmark still very little attention is paid to the problems of large groundwater extractions.
8. All above human influences tend to accelerate succession, often outcompeting species which would have occurred during slower successional processes or would reappear under cyclic succession. These processes have been reinforced by the fact that after 1900 the traditional direct human exploitation of the dunes (*e.g.* sod-cutting, mowing, grazing) gradually decreased and stopped some decades later. It should be realized that before 1900 the dunes had developed for many centuries under such traditional 'management' methods. Nowadays comparable management methods are used again to restore former successional processes and typical species-rich habitats. There are, however, large regional differences, not only in the frequency and scale of application of such measures but also in strategic views on future dune management (see Box 2 for a first contribution to a discussion on this subject).

Favorable conditions for migrating and breeding birds.

9. Changes in the distribution of habitat types and vegetation structure of composing plant communities usually have large consequences for the ornithological values of the Wadden Sea dunes. The wheatear and red-backed shrike, for example, have strongly declined, due to the development of dense grass dominated vegetations, providing less prey (insects) and nesting opportunity. On the Dutch islands,

numbers of breeding hen harriers and short-eared owls have declined. A probable cause may be the increased scrub vegetation due to atmospheric nutrient input, although decreased prey abundance (rabbits) might also be responsible. The important relationship between the adjacent landscapes (polders, salt marshes, mud flats) and general population developments of birds will be discussed in chapter 12 'Birds'.

9.2.5 Conclusions

- Natural dynamics of beaches at head and tail ends of islands have increased due to major reduction of coastal protection measures. In the central parts of the islands, however, practically all dunes have remained fixed and the area with embryonic dunes, white dunes and primary dune slacks has not substantially increased. In general, areas with free blowing sand are still very limited.
- About two thirds of the Wadden Sea dunes consist of mid-successional vegetation types in which eutrophication has caused dense grass vegetations to develop. The more open and species-rich grey dunes and secondary pioneer vegetations have further decreased.
- Species-rich dune slack vegetations have degraded on some of the islands due to groundwater extraction, causing an accelerated succession to drier communities.
- Accelerated succession in wet and dry dune vegetations is currently being remedied by application of traditional style management measures, restoring successional processes and typical species-rich habitats.
- The Wadden Sea dunes qualify for the EC Birds Directive, especially as a breeding habitat for a number of species. Some species characteristic of open dune areas, however, have strongly declined, due to the development of dense grass-dominated vegetations. Increased scrub vegetation led to a decline in numbers of some characteristic birds of prey on the Dutch islands. Probably also a decreased prey abundance (rabbits) plays a role.
- Various dune types are to be protected with highest priority according to the EC Habitats Directive.

9.2.6. Recommendations

The recommendations 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 common monitoring program in the Wadden Sea dunes, recognizing the newly developed TMAP classification for dunes, 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 reestablishing 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.

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