

6. Introduced Species

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Pacific (Japanese) oyster
(*Crassostrea gigas*)
(Photo: N. Dankers)

6.1 Introduction

A major component of global change in the biosphere is the introduction of species across natural barriers. If this process continues at present rate, the result will be a complete mix of biota from all climatically similar biogeographical provinces around the world. The young, relatively species-poor Wadden Sea will have to accommodate more and more species, particularly from shores with higher biodiversity such as the Pacific regions. Once introduced marine species have become established, there is no way to eliminate or to control their populations without harming other components of the ecosystem. The only way to stem the advancing tide of non-native immigrants is to prevent further introductions. Does the current status provide sufficient evidence that swift action is required? To answer this question it is necessary to evaluate the effects of introduced species on native biota and human affairs.

At the North Sea coast, introduced algae and invertebrates arrived via shipping or via aquaculture. They most often became established within estuaries and on hard substrates, with more than 80 known species of which about 52 also occur within the Wadden Sea (Table 6.1; Reise *et al.*, 2002). While many seem to remain insignificant additions to the native biota, the focus of this status report is on the few species that have the potential to attain high abundance, to alter the habitat, and to displace residents. In addition, some introduced phytoplankton species occasionally form conspicuous blooms in the coastal waters. Such species include the toxic flagellates *Gymnodinium mikimotoi* (syn. *Gyrodinium aureolum*) and *Fibrocapsa japonica*, and the non-toxic dia-

toms *Odontella sinensis*, *Thalassiosira punctigera* and *Coscinodiscus wailesii*. This chapter provides an update of the 1999 QSR (de Jong *et al.*, 1999) that contained information on introduced species scattered over different sections. For the introduced species *Rosa rugosa* and the moss *Campilopus introflexus* see chapter 9.2 'Dunes'.

6.2 Introduced species – a selection

6.2.1 *Spartina anglica* (Cord-grass)

The cord-grass *Spartina anglica*, a fertile hybrid of *S. maritima* and *S. alterniflora*, was introduced into the Wadden Sea in the 1920s to promote sediment accretion. It grows as a pioneer plant in the upper tidal zone, where it has colonized most sheltered shorelines, occurs in coherent swards at the seaward front of salt marshes and in patches on the tidal flats between the spring and neap high tide line. Often, a conspicuous, almost monotypic, belt of *S. anglica* is formed. Sediment retention may finally give an advantage to other salt marsh plants. A dynamic mosaic often develops in the lower salt marsh zone where *S. anglica* patches

Table 6.1:
Number of introduced
species which became
established in the Wadden
Sea, and their origin and
mode of transport. Where
two alternatives are
assumed to be equally
alike, a species is counted
twice, if unknown no entry
is made (from data in
Reise *et al.* 2002, and
unpubl. data)

Major group	Number of species	Origin		Brought in by ship	
		Atlantic	Pacific	aquaculture	
Phytoplankton	9	1	8	5	3
Macroalgae	12	1	11	3	10
Poaceae	1	1	0	1	0
Cnidaria	4	2	2	4	0
Nematoda	1	0	1	0	1
Mollusca	9	6	3	4	3
Annelida	4	2	2	4	0
Crustacea	11	5	6	11	0
Asciidiaceae	1	0	1	1	0

may alternate with those of *Halimione portulacoides*, *Puccinellia maritima* or *Artemisia maritima* and others. On upper tidal flats the cord-grass displaces the glass-wort *Salicornia stricta*, seagrass *Zostera noltii*, the lugworm *Arenicola marina* and associated species.

Recently *S. anglica* seem to have spread again in the northern Wadden Sea. Locally, this may be due to reduced domestic grazing pressure on salt marshes but more generally this introduced plant may take advantage of higher spring temperatures over the last two decades (Loebl *et al.*, in prep.). The genus *Spartina* belongs to plants with a C₄ pathway with physiological thresholds of 4 °C for germination and 7 °C for photosynthesis. These threshold temperatures have often been exceeded in April since 1986 but rarely were in the years before. Warmer spring seasons thus could have promoted this neophyte to undergo a recently accelerated spread which might continue with global warming.

6.2.2 *Sargassum muticum* (Japanese seaweed)

This large Pacific alga was unintentionally introduced with oysters to Europe and spread rapidly. The first records are from the English Channel coast in 1973, from the Wadden Sea near Texel in 1980 and near Sylt in 1993. In the Wadden Sea, the Japanese seaweed occurs mainly epizootically attached to mussels and oysters, particularly when these are overgrown with barnacles. It is found in a zone close to low tide line, often slightly below patches of the native bladder wrack *Fucus vesiculosus* (Schories and Albrecht, 1995; Buschbaum, 2005). The alga is perennial with longest thalli occurring in July, up to 2.5 m long but usually less than 1.5 m. Then reproductive branches easily break off and float with their viable gametes and

germlings still attached, enabling wide and rapid dispersal in the tidal waters.

It is rather unlikely that in the Wadden Sea *S. muticum* will displace resident macroalgae as it has been reported for rocky shores. Instead, the large thalli with their multitude of fine branches offer a highly complex phytal habitat for epigrowth and motile fauna (Buschbaum *et al.*, in prep.). Near Sylt 24 algal and 56 invertebrate taxa have been recorded to be associated with *S. muticum*. On the smaller *F. vesiculosus* with its foliose thallus, less than half of that number could be found. This is a case where an introduced species may significantly enrich habitat complexity and species richness around spring low water level in the Wadden Sea.

6.2.3 *Marenzelleria cf. wireni*

This North American estuarine polychaete worm was first recorded for the Wadden Sea in the Ems estuary in 1983, where a large population developed with densities of 2,000–3,000 m², giving rise to a macrozoobenthic assemblage entirely dominated by polychaetes (Essink *et al.*, 1998; Essink, 1999). The worm dwells in vertical burrows and feeds with two palps at the sediment-water interface, has a high tolerance for salinity fluctuations, and reproduces in early spring with pelagic larvae for wide dispersal. The young reach high densities in mud of the upper intertidal, while adults are often more numerous in sand of the lower tidal zone.

Following a lag-phase in the initial population in the Ems estuary, it increased exponentially, then leveled off and eventually declined (Essink and Dekker, 2002). Apparently there were otherwise not fully utilized food sources which could be exploited by this immigrant. The decline remains unexplained. From the Ems, other estuaries in the

Japanese seaweed
(*Sargassum muticum*)
(Photo: C. Buschbaum)



Wadden Sea were invaded within a few years. Colonization of tidal flats beyond the inner estuaries still seems to be in progress. The Balgzand near Texel was reached in 1989. The more marine tidal flats near Sylt were not reached before 2003. At Balgzand and subtidal areas in the western Dutch Wadden Sea *Marenzelleria* strongly decreased during 2003 (Dekker and Waasdorp, 2004). Although there are several other polychaetes of similar size and feeding type in the Wadden Sea, no clear evidence for competitive interactions between the invader and the natives have been found so far. A predecessor, which immigrated in the late 1960s, is the small worm *Tharyx cf. killariensis* of unknown origin and uncertain taxonomic status. It is still common in the Wadden Sea.

6.2.4 *Ensis americanus* (American razor clam)

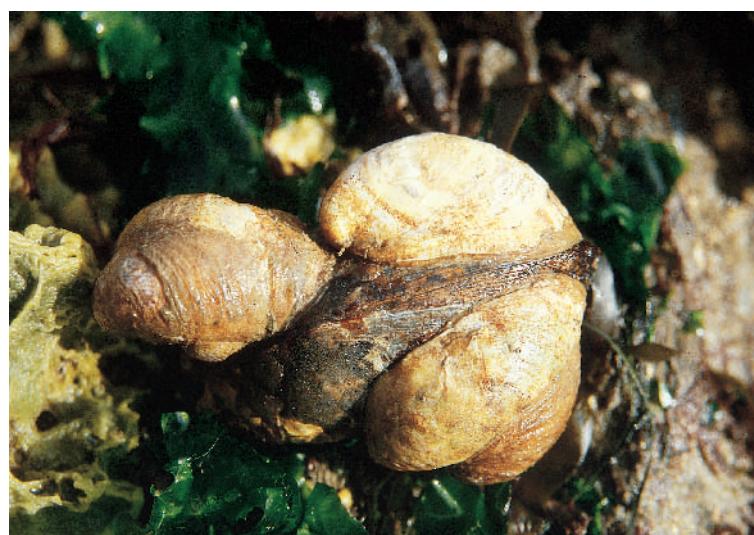
No razor clams occurred in the Wadden Sea before the arrival of *Ensis americanus* (syn. *E. directus*) in ballast water near Helgoland in 1978. By larval and postlarval drifting this species rapidly extended its distribution, approximately 75 km per year in westward direction and 125 km to the north (Armonies, 2001; Essink, 1985). We may learn from this rate of spread that for benthic species with similar dispersal capabilities, studies on local effects require knowledge of population dynamics on a scale of at least 200 km (i.e., half of the coastal length of the Wadden Sea) to differentiate the local phenomena from general trends.

Successful recruitment is rather irregular in the Wadden Sea (Armonies and Reise, 1999; Beukema and Dekker, 1995). Near Sylt, only six strong year-classes were recorded within two decades. Although present in the lower tidal zone, maximum densities occur in shallow subtidal sand in-

cluding the coastal region offshore of the barrier islands, with a biomass similar to that of dense beds of the native cockles and mussels. Very high larval abundances in plankton samples suggest that adult densities are still underestimated due to insufficient sampling gear (M. Strasser, pers. comm.). Significant interactions with native suspension feeders have not been noted so far, although *E. americanus* may now be the most abundant large bivalve in the shallow subtidal. It has become a significant food item for eider ducks and common scoters (T. Jensen, pers. comm.; Leopold et al., in prep.; Wolf and Meiniger, 2004). Contrary to the belief that introduced molluscs may be free of parasites, *E. americanus* contained many of the larval trematodes known from native cockles, however, the intensity of infestation was much lower (Krakau et al., in prep.). Thus, razor clams may constitute a healthier food for final trematode hosts, such as eiders, than native bivalves, although they may be harder to swallow.

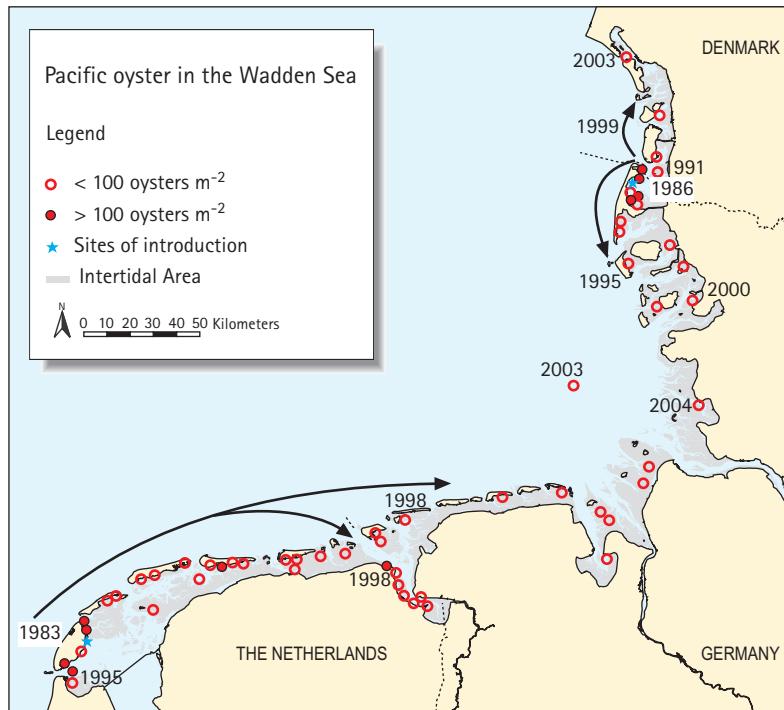
6.2.5 *Crepidula fornicata* (American slipper limpet)

Unintentionally introduced with oysters to Europe in the 1870s, the American slipper limpet *Crepidula fornicata* (L.) is now found from the Mediterranean to Norway. At southern European coasts, especially in France, this epizootic suspension feeder became superabundant, forming thick carpets of individual snails adhering to each other and covering shallow subtidal soft bottoms with up to 9,000 limpets m^{-2} (Blanchard, 1997). Also in the saline lake Grevelingen in the Dutch Delta region such high abundances do occur. In the Wadden Sea abundances are still an order of magnitude lower. However, since the first records 70 years ago, slipper limpets have increased, shifted



American slipper limpet
(*Crepidula fornicata*)
(Photo: C. Buschbaum)

Figure 6.1:
The Pacific oyster
Crassostrea gigas in the
Wadden Sea. Asterisks indicate sites and years
(boxed) of introduction
(Texel, Sylt). Other years
indicate first records of
settlement by larval
dispersal for selected sites.
Circles show mean
abundance in 2003.



their habitat from oyster to mussel beds and locally form monospecific epibenthic assemblages with limpets attached to each other (Thielges *et al.*, 2003). In the Dutch Wadden Sea the species was considered rare, but has increased considerably in the last two years on subtidal mussel beds.

While predation pressure on *Crepidula* is low and parasites absent, and reproduction and growth being similar to that reported from elsewhere, the main limiting factor for population increase in the Wadden Sea is apparently winter mortality (Thielges *et al.*, 2004). Milder winters as a corollary of global warming in the years to come may allow this limpet to attain abundances similar to those reported from further south. This introduced species has the potential to displace other epibenthic suspension feeders. In experiments, limpets increased mortality and decreased growth of mussels to which they attach (Thielges, 2005).

6.2.6 *Crassostrea gigas* (Pacific oyster)

In the Wadden Sea, attempts to restock the depleted oyster beds of the native *Ostrea edulis* failed with imported spat from outside, with American *Crassostrea virginica* or with *C. angulata* from Portugal and France – now considered to be a southern strain or sibling from the Pacific *C. gigas*. Since 1964, the Japanese *C. gigas* has been imported to several places in Europe, including the Wadden Sea. Attempts in the 1970s and 1980s in

Niedersachsen were short-lived (Wehrmann *et al.*, 2000) but at Sylt a thriving culture became established in 1986, primarily with spat taken from British hatcheries (Reise, 1998). *C. gigas* was found in 1983 at Texel, probably brought there deliberately from the Dutch Delta region (Dankers *et al.*, 2004). Natural spread by larvae, and may be also by transport with attached young oysters on ships' hull or on relayed mussels, occurred during the 1990s from Texel and Sylt. In 2003 the records imply that *C. gigas* has achieved a continuous distribution throughout the entire Wadden Sea (Figure 6.1). Because of a good spatfall in 2003 many oyster beds are now rapidly developing into solid reefs at several sites in the region.

While no viable population of the native *O. edulis* is left in the Wadden Sea, the Pacific *C. gigas* is now firmly established. Is this exchange of oyster species neutral to the ecosystem or is it bound to conspicuous change? Although treated as similar at the market, ecologically these oysters are very different. *O. edulis* occurred subtidally and has a narrower tolerance range for temperature and salinity than *C. gigas* which lives primarily in the intertidal. Due to partial brooding, *O. edulis* produces less larvae which remain in the plankton for only a few days with limited dispersal, which is in contrast to the more numerous and widely broadcasted eggs and larvae of *C. gigas*.

Near Texel and Sylt development has locally advanced from solitary oysters to coherent reefs

where subsequent generations attach to each other. This development may take 5 to 10 years (Dankers *et al.*, 2004). In contrast to most native bivalves with spawning in spring and early summer, *C. gigas* spawns in July and August. Successful recruitment did not occur every year. Near Sylt, years with high recruitment were those with highest temperatures in July and August (Diederich *et al.*, 2005). Thus, *C. gigas* in the northern Wadden Sea may benefit from global warming. Spat is difficult to find in the field and recruitment success is best assessed after one year when oysters have attained a shell diameter of 20 to 50 mm or more. In 2003, oyster sizes over 180 mm were common, and the largest specimen found in the Wadden Sea was of the gigantic size of 310 mm (Dankers *et al.*, 2004). This indicates that *C. gigas* may survive to old age in this region.

Solid calcareous reefs are a completely new biogenic structure for the Wadden Sea and may give rise to a biocoenosis very different from the one described by Karl Moebius (1877) for the native oyster beds. Once abundant, these reefs may considerably alter patterns of sediment erosion and deposition in the Wadden Sea. Although attaching to any kind of hard substrate, sites with living mussel beds or plenty of dead mussel shells, are the most frequent localities where *C. gigas* abounds and reef formation is commencing. This overgrowth and pre-emption of space, and possibly also competition for phytoplankton and filtering of larvae, may eventually diminish the still dominant cockles and mussels in the Wadden Sea. In the Eastern Scheldt almost 5% of tidal and subtidal sediments are covered by *C. gigas*, and in this semi-enclosed embayment such effects are already assumed to take place (Geurts van Kessel *et al.*, 2003).

Preliminary experiments and observations suggest that predation pressure by starfish, crabs and birds on *C. gigas* is lower than on native bivalves. The trematode parasite *Renicola roscoffita* which takes periwinkles as first, cockles and mussels as second intermediate host and gulls and eider ducks as final host, is also infesting *C. gigas* but at lower intensity (M. Krakau, pers. comm.). Thus, provided no efficient predators on these oysters nor viral diseases become introduced, *C. gigas* is expected to take over in the Wadden Sea, both as an ecosystem engineer generating solid reefs and as a competitive suspension feeder.

No control is feasible which would not also harm other components of the Wadden Sea ecosystem. Harvesting wild *C. gigas* is unlikely to be effective and oysters cemented to each other in

the reefs and larger in size than a human hand cannot be sold on the market.

6.3 Conclusions

We have singled out from some 52 introduced species six which already do have or which are about to have strong effects on habitat properties and native biota in the Wadden Sea. None of these cause any immediate harm to human health and economy nor do they offer a great benefit except for Pacific oysters in culture. These targeted species differ in their effects, some of which may be 'good' (i.e., sediment retention by *Spartina*, habitat provision by *Sargassum*, more food for birds by *Ensis*) and others 'bad' (i.e., displaced seagrass by *Spartina*, overtaking mussels by *Crassostrea*). The suspension feeder compartment in the coastal ecosystem will become strengthened and crowded by *Ensis*, *Crepidula* and *Crassostrea*, probably resulting in a major trophic regime shift. Global warming may benefit *Spartina*, *Crepidula* and *Crassostrea* in the coming years, resulting in further changes in dominance. Some introductions have become extremely numerous locally, such as *Marenzelleria*, and still we lack sufficient knowledge to even guess what the community effects will be. In any case, species introductions have considerably speeded up the rate of ecological change, calling into question the long-term utility of quality standards derived from present species assemblages.

Are these six introduced species threatening 'A healthy environment which maintains the diversity of habitats and species, its ecological integrity and resilience as a global responsibility', this written as a shared vision in the Trilateral Wadden Sea Plan (1997). There is no evidence that introduced species have caused the extinction of natives in the Wadden Sea (Wolff, 2000). 'Ecological integrity' is a vague term and may either imply in analogy to the territorial integrity of nations that the areal extent should not be reduced, or in analogy to personal integrity that the character should remain clear, uncorrupted and intact. The targeted six species are changing habitats, functions and species compositions in the ecosystem to some extent, and even to the untrained observer the tidal seascape will never turn again to be the same. 'Resilience' is defined as the ability to return to a previous state after a disturbance. To what extent this ability with and without introduced species is different may be determined only with a set of controlled experiments. However, results would strongly depend on the choice of disturbances, and a clear answer cannot

be expected. From the fact alone that these introduced species are so successful in their recipient environment, one may infer that resilience is rather high, unless the introduced species itself is considered to be the disturbance. There is no indication that established non-native immigrants will ever leave the Wadden Sea again.

As species introductions are irreversible and accumulating over time, this issue may be considered to be more important than reversible effects of overfishing, eutrophication and contaminants. For the Wadden Sea the net effect of unhampered introductions would be a regional increase in species richness and a growing biotic similarity with other coasts. The unique character of the Wadden Sea would still be manifest in the physical environment but not any more in its living component.

6.4 Recommendations

Introduced species as such do not constitute a threat. Some deliberate introductions are at least economically beneficial, and most others have remained minor components in the Wadden Sea ecosystem. Unfortunately, attempts to predict which species among the immense spectrum of potential introductions are likely to become problematic have had a low success. The 'innocent until proven guilty' philosophy is inadequate in this case and should be replaced by 'guilty until proven innocent' (Simberloff, 2003). This requires comprehensive assessments of proposed introductions. This was not done with the oysters introduced into the Wadden Sea. Most introductions, however, were not intended. To reduce the rate of such in-

trodictions, effective precautionary measures are in need (Nehring and Klingensteiner, 2005). Because of the high potential for natural dispersal in introduced species, and many human vectors for secondary dispersal along European coasts, adequate precautionary measures are beyond a trilateral management plan. For example, a decision not to introduce Pacific oysters for culturing would have merely postponed the invasion unless at European coasts outside the Wadden Sea the same decision would have been made. To protect the 'ecological integrity' of the Wadden Sea, European-wide solutions need to be supported. To provide sufficient reasons for these, thorough analyses of the impacts caused by the already introduced species are a necessary prerequisite. Compared to other regions, the Wadden Sea may have had good luck with the immigrants so far with the possible exceptions of toxic flagellates in the phytoplankton and of the Pacific oyster. One single introduced species may be able to cause severe ecological change, economic damage or a threat to human health, and this might be the next species about to arrive or one which is already there but its full impact has not yet been realized.

The TMAP should be able to discover new immigrant species. Adaptations of the TMAP may be necessary in order to provide the data for evaluating the possible impact on resident biological communities. Furthermore, it might be useful to consider the development of a trilateral policy on how to deal with invasive introduced species (Nehring and Klingensteiner, 2005).

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7. Salt Marshes



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Salt marsh on Hallig Gröde
(Photo: M. Stock)

7.1 Introduction

Salt marshes form the upper parts of the intertidal zone, the interface between land and sea, and are strongly controlled by geomorphological, physical and biological processes, such as sedimentation in interaction with the vegetation, tidal regime and wind-wave pattern. They constitute a habitat for a wide range of organisms. On a European scale, among 1,068 plant species that are bound to coastal habitats, nearly 200 are restricted to salt marshes (van der Maarel and van der Maarel-Versluys, 1996). The highest species diversity in salt marshes is found among the invertebrate fauna; about 1,500 arthropod species inhabit salt marshes of which a considerable number are restricted to this habitat (Heydemann, 1981). Salt marshes provide resting, breeding and feeding grounds for a number of birds. Coastal waders which feed on the intertidal flats use the salt marshes as roost during high tide (Meltotte *et al.*, 1994; Ens *et al.*, 1999; Koffijberg *et al.*, 2003). A number of migratory birds such as brent goose and barnacle goose use the salt marshes to replenish their body reserves to reach their northern breeding grounds (Madsen *et al.*, 1999; Blew *et al.*, 2005). There are various human activities which have or may have an impact on salt marshes, including coastal defense measures, land use and management (grazing, cutting), pollution and eutrophication, fisheries, hunting and tourism (for details see 1999 QSR).

7.1.1 Protection and management

Mainland salt marshes have been embanked for centuries and the extent today is only the relic of a previous widespread transition zone between fresh, brackish and saline habitats. Nowadays, all salt marshes in the Wadden Sea area are under national nature protection. Besides the national legislation and nature protection regulations, the Wadden Sea Plan with specific targets for the salt marshes provides the framework for the habitat management (Trilateral Wadden Sea Plan, 1997). The aim is to maintain and, where possible, to extend the area of salt marshes. In general, it is the aim to reduce human interference with salt marshes and to enhance natural development by reducing the intensity of drainage and grazing in order to gain a high biodiversity in the entire Wadden Sea Area. Coastal protection activities, such as protection of salt marsh edges or seawall rein-

Targets

- An increased area of natural salt marshes
- An increased natural morphology and dynamics, including natural drainage patterns, of artificial salt marshes, under the condition that the present area is not reduced
- An improved natural vegetation structure, including the pioneer zone, of artificial salt marshes
- Favorable conditions for migrating and breeding birds

forcement, are carried out in coordination with nature protection needs, e.g. by applying Best Environmental Practice (Policy Assessment Report 2001; see also chapter 2.1 'Coastal Defense').

Salt marshes are also protected within the EC Habitats Directive (Annex I habitat types 1310 Salicornia, 1320 Spartina swards, 1330 Atlantic salt meadows) which provides a European network of special areas of conservation 'Natura 2000' (Balzer *et al.*, 2002).

7.1.2 Outcome of the 1999 QSR

The salt marsh chapter of the QSR 1999 focused on a description of the salt marsh types found in the Wadden Sea area and on human influences on the habitat. Data from Dijkema *et al.* (1984) concerning surface area, geomorphological type, management, threats and protection of all salt marsh sites was updated (van Duin *et al.*, 1999). The main conclusion was that progress has been made in improving the natural situation in (artificial/man-made) salt marshes with respect to geomorphology, dynamics and vegetation and a reduction of livestock grazing has been achieved. De-embankment of summer polders was considered a good practice to increase the salt marsh area and maintain the sediment balance of the tidal area. The 1999 QSR also observed that harmonized quality criteria for salt marshes and a comprehensive inventory of actual data were still missing.

7.2. Status

7.2.1 Total area of salt marsh types

Salt marshes develop in close interaction of hydrodynamic processes with vegetation develop-

ment and can be distinguished in relation to their geomorphologic features (Dijkema, 1987). On the islands, four types could be distinguished. Barrier-connected salt marshes develop on the lee side of the sand dune system of the barrier islands. Green beaches are salt marshes which developed on the North Sea side of the islands. In addition to the categories in the 1999 QSR, salt marshes in summer polders and in de-embanked summer polders have been included.

On the mainland, foreland marsh (including the estuarine salt marshes), salt marshes in summer polders and de-embanked (summer) polders are the main salt marsh types. Most foreland marshes have been developed from sedimentation fields protected by brushwood groynes. As a special case, the salt marshes in St. Peter-Ording (Schleswig-Holstein) and Skallingen (Denmark) have been added as barrier-connected type, because they have developed in the shelter of a beach-barrier system comparable to the barrier islands.

Hallig salt marshes have been accreted on surviving parts of marshes flooded in the past and are highly exposed to wave energy. They represent a separate type as they resemble more the mainland foreland type.

A trilateral overview of the surface area for the different types is given in Table 7.1 and Figure 7.1. The border between the pioneer zone and bare soil is chosen at 5% coverage (10% in SH). This is based on practical reasons when mapping from aerial photos.

Because of methodological differences, a direct comparison on trilateral level with the figures given in the 1999 QSR could not be made. The 1999 QSR figures were partly calculated with-

Table 7.1:

Area of salt marsh types (ha) in the Wadden Sea region. The areas include the pioneer zone, except for Niedersachsen and Denmark.

Salt marsh type	The Netherlands Years 1995-2002	Niedersachsen* 1997	Hamburg 1995-1998	Schleswig-Holstein 2001-2002	Denmark** 1995-2000	TOTAL
1. Barrier islands						
A barrier-connected (incl. foreland)	3,500	2,820	140	1,130	2,554	10,144
B green beaches	380	310			1,780	2,470
C1 summer polder		60	80			140
C2 de-embanked (summer) polder	45	150	40			235
2. Mainland						
A barrier-connected				730	1,657	2,387
B foreland marsh	4,000	5,430		7,470	2,670	20,635
C1 summer polder	960	1,540			49	2,549
C2 de-embanked summer polder	295	90				385
3. Halligen						
	45			2,110		2,155
Total	9,230	10,400	260	11,440	8,710	39,680

* Niedersachsen: including creeks, excluding pioneer zone.

** DK: excluding pioneer zone; data on green beaches from 1999 QSR; barrier-connected salt marsh type on mainland: Skallingen peninsula; summer polder: saltwater lagoon behind 'Det Fremskudte Dige'.

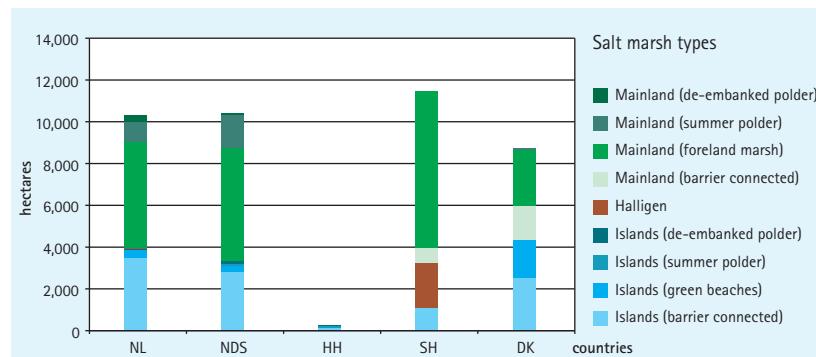


Figure 7.1:
Surface area (ha) of the different salt marsh types in the Wadden Sea (see Table 7.1), including pioneer zone except for Niedersachsen and Denmark (border between the pioneer zone and bare soil is chosen at 5% coverage respectively 10% in SH).

out *Salicornia* pioneer vegetation or were estimated on the basis of expert knowledge and thus do not refer to recent standard methods of area calculation, e.g. via aerial photography and GIS tools.

Monitoring in Schleswig-Holstein, Hamburg and Niedersachsen showed an increasing salt marsh area. In Schleswig-Holstein, a comparison of the extent of mainland salt marshes between 1988–2001 reveals an increase of about 16% (700 ha, excluding the pioneer zone). As well as the general increase in the area, local losses occurred and were mainly due to poor sedimentation conditions or to erosion of the intertidal flat area adjacent to the marsh (Stock *et al.*, 2005).

The Hamburg salt marsh area is constant on Neuwerk due to the fixation of the island, whereas it is increasing in the undisturbed areas of the barrier islands of Scharhörn and Nigehörn.

In Niedersachsen, a comparison of the situation in 1966 and 1997 of the whole salt marsh area based on aerial photographs showed a natural increase of the salt marsh surface area of about 2,700 ha, in the bays (approx. 610 ha), on the southern part of the islands (approx. 1,130 ha) and an increase in areas protected by brushwood groynes along the coast (approx. 1,000 ha). Salt marsh decrease (approx. 230 ha) mainly took place along the coast in areas without brushwood groynes or in an exposed situation, for example on the eastern part of the Weser estuary (Bunje and Ringot, 2003).

The area of barrier-connected salt marshes in The Netherlands is still growing, particularly at the eastern point of some islands such as Schiermonnikoog and Rottumerplaat, except Rottumeroog. On the latter island the management of the dunes has stopped, which results in erosion on the North Sea side. De-embankment of summerpolders was also considered favorable to create or restore fresh-salt transitions. Recent examples are green beaches on the island of Terschelling and Kroon's

Polders on the island of Vlieland (Esselink *et al.*, 2003).

The mainland marshes in the old land reclamation works, without the brackish Dollard, increased by 200 ha and 50 ha between 1988 and 2002, in Friesland and Groningen, respectively (Dijkema *et al.*, 2004). On Groningen mainland, the salt marsh area is still 150 ha less than 30 years ago and the pioneer zone is decreasing.

In Denmark no precise calculations of the development in salt marshes have been made in recent years. However, the area of salt marshes which are protected by the nature protection act was mapped in the middle of the 1990s. This exercise covered the area of unbroken salt marsh vegetation, and makes up a total of 6,930 ha. In addition to this, an unknown area of green beaches with salt marsh vegetation is found on the island of Fanø and especially on Rømø. This makes up a total of 8,710 ha which is slightly larger than the one given in the 1999 QSR (8,350 ha). The size of the barrier-connected salt marshes on the peninsula of Skallingen is still decreasing to the south, whereas a still growing area is found on Keldsand (presently about 50 ha), which is a high sand just east of the southern tip of Fanø. Along the mainland, a new formation of salt marsh has developed in front of the mouth of the river Kongeåen during recent decades, and an increasing vegetation cover is developing in front of Det fremskudte Dige near Højer in the south.

7.2.2 Salt marsh zones

Three main salt marsh zones with different vegetation can be distinguished: the pioneer zone where plant growth starts at about 40 cm below mean high tide (MHT); the low marsh, inundated during mean spring tides (100–400 floods/year), and the middle/high marsh with less than 100 floods per year. In addition, the sandy green beach and the brackish marsh can be differentiated by a special type of vegetation. Adjacent to the salt

marshes fresh (anthropogenic) grassland occurs. The different zones have been defined by vegetation types (see Table 7.2). The criteria of all the types are available in more detail in a vegetation typology key.

Based on the definition given in Table 7.2, the available vegetation data could be harmonized into a trilateral GIS database with a high spatial resolution of 1:5,000 to 1:10,000. (Figure 7.2 and 7.3)

For the first time, a comprehensive overview of all Wadden Sea salt marshes and the vegetation zones could be prepared and the distribution of the different zones could be described in detail (Figures 7.4). This gives a sound foundation to follow the future development of the salt marshes for the whole Wadden Sea area.

The mainland salt marshes have a clearly different character than the island salt marshes; due to coastal protection activities the artificial mainland salt marshes showed a high proportion of pioneer zone compared to the islands (Figure 7.4).

On the Niedersachsen coast, the major part of the observed 1,600 ha fresh grasslands is located at the Wurster Küste where the proportion of summer polders is higher compared to other areas.

In The Netherlands, the salt marshes are mainly located on the islands and the Eastern Wadden Sea, whereas only a few salt marshes are left in the Western parts.

In Denmark, no mapping of the different salt marsh zones has been performed.

Table 7.2:
Salt marsh zones 1–6 and
vegetation types (TMAP
No. 0.0 – 6.1) as defined by
the TMAP Salt Marsh
Workshops 2003–2004.

TMAP No.	TMAP code	Vegetation typology	Habitats Directive Type
	Head-zone type		
0	S u	No information about zone and vegetation type	-
0.0	S u*	Salt / brackish landscape, unspecific	
0.1	S w	bare water	
0.2	S s	bare soil, sand (beaches etc.)	
0.3	S m	bare soil, mudflat	
1	S P	Pioneer salt marsh	
1.0	S P*	Pioneer salt marsh, unspecific	1310
1.1	S Ps	Spartina anglica type	1320
1.2	S Pq	Salicornia spp. / Suaeda maritima type	1310
2	S L	Low Marsh	1330
2.0	S L*	Low Marsh, unspecific	
2.1	S Lp	Puccinellia maritima type	
2.2	S Ll	Limonium vulgare / Puccinellia maritima type	
2.3	S La	Aster tripolium / Puccinellia maritima type	
2.4	S Lh	Atriplex portulacoides / Puccinellia maritima type	
3	S H	High marsh	1330
3.0	S H*	High Marsh, unspecific	
3.1	S Hl	Limonium vulgare / Juncus gerardi type	
3.2	S Hj	Juncus gerardi / Glaux maritima type	
3.3	S Hf	Festuca rubra type	
3.4	S Hh	Atriplex portulacoides / Artemisia maritima type	
3.5	S Hz	Artemisia maritima / Festuca rubra type	
3.6	S Hm	Juncus maritimus / Festuca rubra / Juncus gerardi type	
3.7	S Hy	Elytrigia atherica type	
3.8	S He	Carex extensa type	
3.9	S Hx	Atriplex prostrata / Atriplex littoralis type	
3.10	S Hg	Agrostis stolonifera / Trifolium fragiferum type	
3.11	S Hc	Plantago coronopus / Centaurium littorale type	
3.12	S Ho	Ononis spinosa / Carex distans type	
3.13	S Hr	Elytrigia repens type	
4	S G	Green beach, sandy pioneer	1330
4.0	S G*	Sandy green beach, unspecific	
4.1	S Gf	Elytrigia juncea type	
5	S B	Brackish marsh	1330
5.0	S B*	Brackish marsh, unspecific	
5.1	S Bb	Bolboschoenus + Schoenoplectus type	
5.2	S Bp	Phragmites australis type	
5.3	S Bg	Brackish flooded grassland type	
5.4	S Bm	Juncus maritimus / Oenanthe lachenalii type	
6	S F	Fresh (anthropogenic) grassland	-
6.0	S F*	Fresh (anthropogenic) vegetation, unspecific	
6.1	S Fl	Lolium perenne, Cynosurus cristatus and other fresh species type	

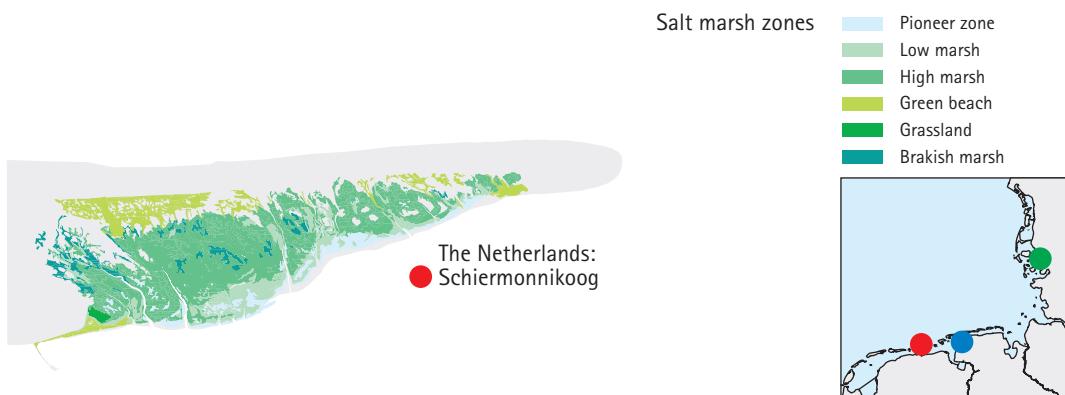


Figure 7.2:
TMAP salt marsh zones.
Examples from different
locations in the Wadden
Sea (source: TMAP Data
Unit).

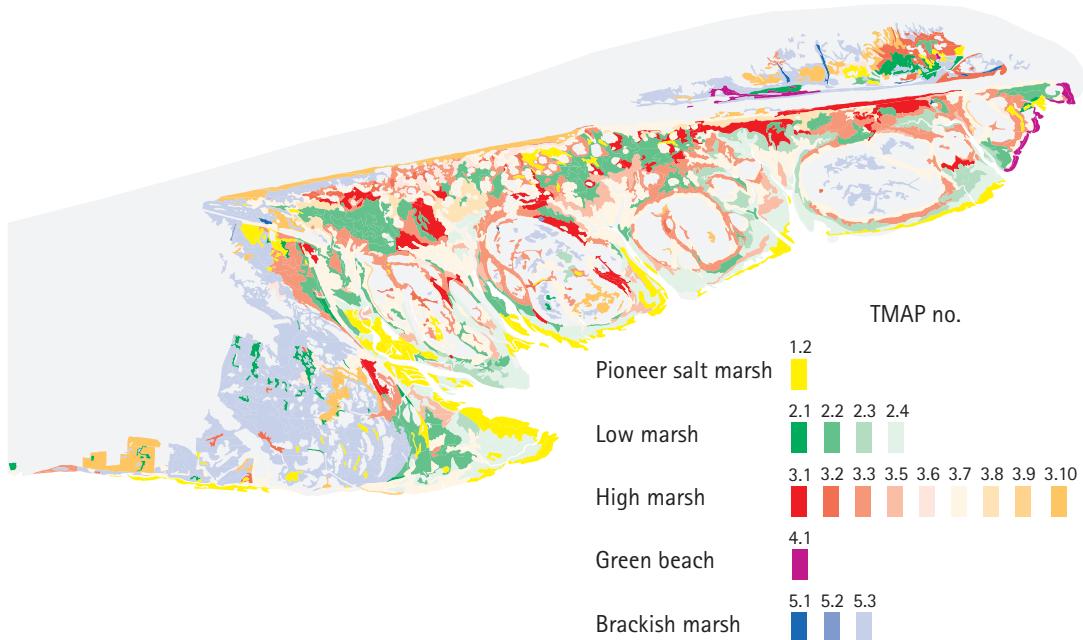
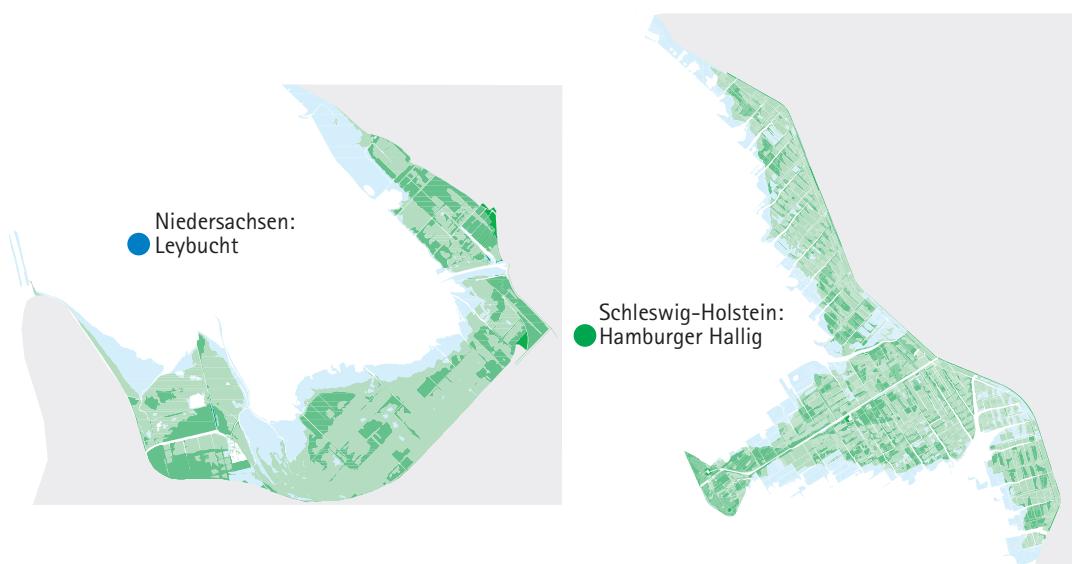
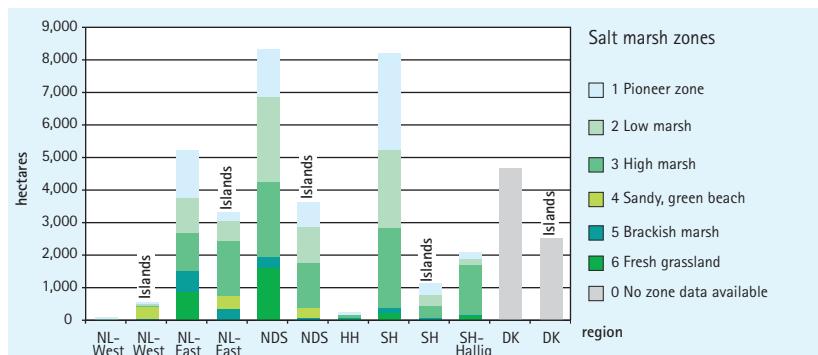


Figure 7.3:
TMAP salt marsh
vegetation types. Detailed
map of the marshes on the
island of Terschelling, The
Netherlands
(source: TMAP Data Unit).

Figure 7.4:
Distribution of mainland (left bar) and island (right bar) salt marsh zones (ha) in The Netherlands (NL) (east and west of Terschelling watershed), Niedersachsen (NDS), Hamburg (HH), Schleswig-Holstein (SH) (islands and Halligen separately), no data available from Denmark (DK). Data source: TMAP Data Unit, data of the period 1997-2001 (pioneer zone: coverage >5%, for SH >10%).



7.2.3 Drainage

Drainage on salt marshes is mainly carried out as a drainage of the seawall for coastal protection reasons and to allow agricultural exploitation of the marsh. In order to increase the natural morphology of artificial salt marshes (Wadden Sea Plan Target), the reduction or cessation of systematic drainage in the salt marsh accretion zone has proven to be a good method.

In Niedersachsen and Schleswig-Holstein most parts of the mainland salt marshes and some parts of the island marshes were drained in the past. With the foundation of the National Parks in 1985 and 1986 and the reduction of the agricultural exploitation (grazing, cutting) of the marshes, the drainage measures were also reduced. Today, drainage in most salt marsh areas is carried out only in a small strip along the seawall to guarantee the drainage of the dike foot itself and to the salt marshes which are still used for agricultural and coastal protection purposes, e.g. sod cutting. On the islands, drainage measures in the unused salt marshes, for example at the eastern parts of the East Frisian islands, have totally stopped. As a result artificial drainage measures have been reduced to about 2,200 ha during the past ten years in Niedersachsen and to about 1,800 ha in Schleswig-Holstein.

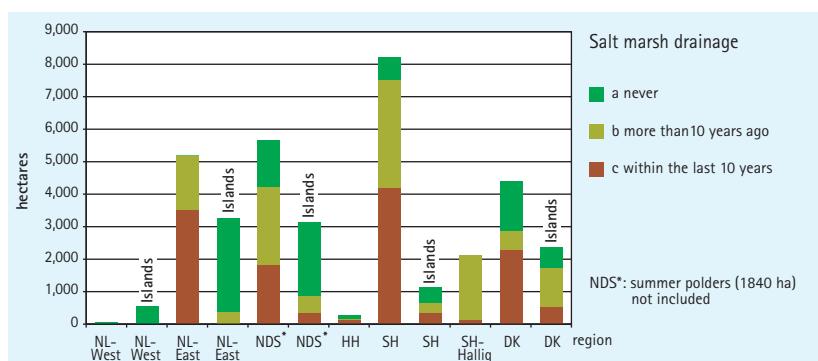
In Hamburg the maintenance of regular drainage ditches in front of the summer polder has been discontinued for many decades. Nevertheless the

outflow of the main summer polder-creeks was kept in good condition. In 2004 a project was implemented to renew the tidal influence for the eastern part of the Neuwerk summer polder (National Park Zone I).

In The Netherlands, maintenance of ditches on mainland salt marshes decreased after 1989 and stopped totally in 2001 due to the implementation of a more natural management (Dijkema et al., 2001). In the same period the brushwood groynes have been optimized and restored, but in 2004 almost all maintenance work to the groynes has been stopped due to the cut off of funding. As natural creek systems develop in the initial stages of marsh formation, it is too soon to know if and how creeks will develop in the long run in artificially drained salt marshes after the recent cessation of drainage measures.

In Denmark, drainage of coastal tidal flats and mature salt marshes has also been reduced in recent years, but no exact calculations of the size of the area and the different types of drainage have been made. Since 2000, only drainage systems at the foot of most seawalls and in some places along the Rømø Dam have been maintained. The maintenance of brushwood groynes, ditches in sedimentation fields and other coastal protection measures has also been given up in most places, and only where it is strictly necessary to the security of seawalls and dams are the systems still kept up.

Figure 7.5:
Salt marsh areas (ha) with different types of drainage (2002), differentiated for mainland (left bar) and islands (right bar).
a: no artificial drainage at all; b: no artificial drainage on a regular basis in the past ten years, c: artificial drainage measures have been carried out during the past ten years (Nds* = summer polders (1,840 ha) and pioneer zone in Niedersachsen not included). Data source: TMAP Data Unit.





Ungrazed salt marsh on Skallingen peninsula
(Photo: M. Stock)

7.2.4 Land use and management

Land use can be subdivided into agricultural exploitation and nature conservation. The respective areas are not (yet) quantified. Within agricultural exploitation and nature conservation management practices such as grazing, cutting, abandoning are recognized and quantified. In general, the intensive agricultural exploitation of salt marshes observed has decreased during the past two decades. Today, large areas of the salt marsh are grazed moderately, often for nature conservation purposes, for example for geese management on the Halligen in Schleswig-Holstein. The terms 'no grazing', 'moderate grazing', 'intensive grazing' and 'cutting' are defined by the canopy of the vegetation and its heterogeneity, and thus describe the real grazing situation of a certain area irrespective of the stocking density, namely, intensive grazing = overall short sward, no grazing = overall tall canopy, moderate grazing = pattern of low sward and tall canopy (Figure 7.6).

By comparing the recent situation with information from the 1980s (Kempf *et al.*, 1987), the last Wadden Sea wide review available, a decrease of intensively used areas could be observed. In using these historical figures, it has to be taken

into account that, because of methodological differences, the figures by Kempf *et al.* (1987) cannot be compared directly with the figures compiled later and from other sources. However, they give an indication about the general trend since the 1980s.

In The Netherlands, only data from Kempf *et al.*, 1987 was available for the 1980s. Although this data cannot directly be compared with the recent data, it was taken to illustrate the general trend in land use of salt marshes during the past 20 years (Figure 7.7). It can be shown that the proportion of the intensively grazed mainland salt marshes decreased from about 61% to now 28% and the area with moderate grazing (grazing management) shows a clear increase from 17 to 51%. On the islands, areas with no land use increased from 61% to 70% (Figure 7.7).

In Niedersachsen, the area of salt marshes without grazing and cutting increased from 53% in the 1980s to 66% in 1999. Intensively used areas decreased in the same period from 23 to 11%. The percentage of areas with moderate grazing remained almost the same (Kempf *et al.*, 1987; NLPV 2001). In 2003 the percentage for the total salt marshes was 70% no grazing, 18% moderate

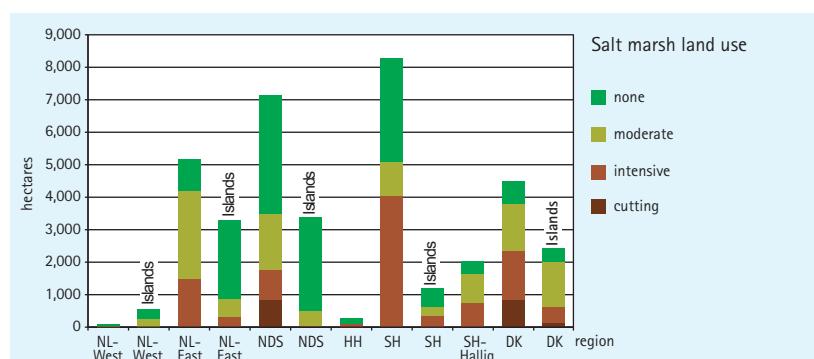
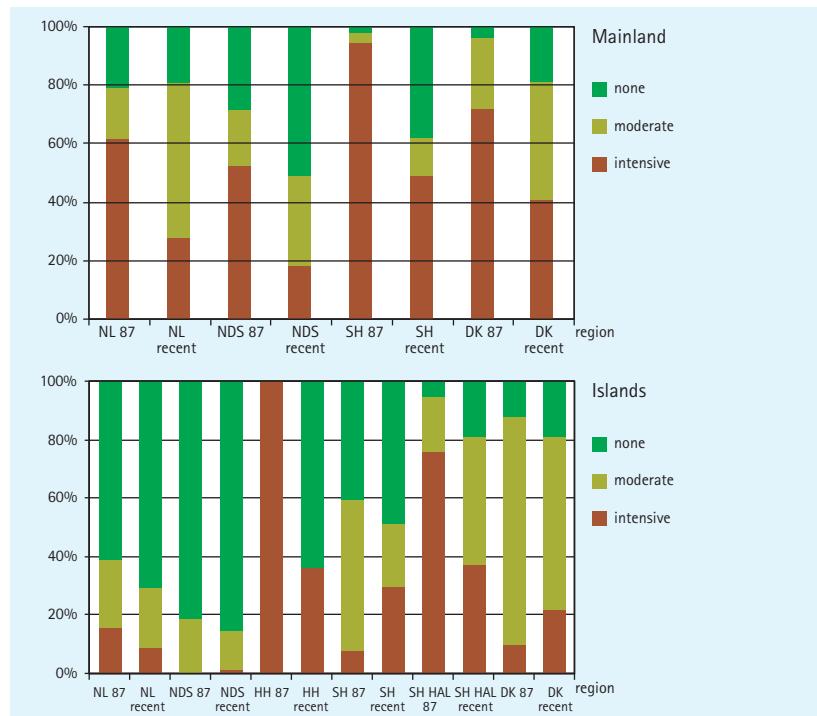


Figure 7.6:
Distribution of land use by livestock grazing (none, moderate, intensive) and cutting (in ha) in the Wadden Sea salt marshes on the mainland coast (left bars) and the islands (right bars) (data of the period 2001/2002); pioneer zone in Niedersachsen not included). Data source: TMAP Data Unit, data of the period 1997 – 2001

Figure 7.7:
Development of land use by livestock grazing in the Wadden Sea salt marshes (mainland and islands), comparison between data from the 1980s and recent data (period 1999/2002). (Sources 1987: Kempf *et al.*, 1987; recent data from TMAP Data Unit).

none = overall tall canopy; moderate = diverse vegetation canopy; intensive = overall short vegetation canopy.
 Kempf 1987: intensive: very intensive grazing and intensive grazing (more than 3 sheep or 1 cattle per ha); moderate: moderate grazing (less than 3 sheep or 1 cattle per ha), none: no grazing or cutting.



(Explanatory note: Because of different methods used in the calculation of the surface area and different data sources, the figures from previous inventories (Kempf *et al.*, 1987) cannot directly be compared with the recent results. However, they have been included here to illustrate the general trend in land use of salt marshes during the last 20 years).

grazing, 4% intensive grazing and 8% cutting.

In Hamburg, the number of grazing cattle and horses on the island of Neuwerk has decreased substantially within recent years. Nevertheless the grazing intensity in the remaining area (Zone II) is high although there is less than 1 animal/ha. On the other hand, in the years 1993–2002, the area of moderate use respectively no grazing increased substantially from zero to 63% (Zone I).

In Schleswig Holstein, the percentage of inten-

sively grazed foreland salt marshes decreased from 80% in the 1980s to 33% in 1999. Areas with no grazing increased to 42%, areas with moderate grazing increased to 25% (Stock and Kiehl, 2000). Based on a survey of real land use in 2001/2002 the situation for the total salt marsh area is as follows: 36% are ungrazed, 19% are moderately grazed and 45% are still intensively grazed (Stock, pers. comm.). The changes between 1999 and 2001/2002 are mainly due to two reasons. In 1999



Intensively grazed salt marsh at Helmsand, Schleswig-Holstein
(Photo: M. Stock)

the assessment was only based on expert knowledge and the leasing situation of the state-owned marshes whereas the recent overview is based on TMAP definition settings according to the canopy height of the vegetation.

In Denmark, the situation has not changed much throughout the 1990s compared to that in 1987, when about 45% of the salt marshes were intensively grazed (10% on the islands and 75% on the mainland) (Kempf *et al.*, 1987). Detailed information about the grazing intensity was so far only available from the northern part, Ribe County (Frikke *et al.*, 2002). Here, the proportion of intensively grazed areas even increased from 30% (1989) to 40% (2000), the proportion of moderate grazing decreased in the same period only slightly (from 57% to 54%). However, a recent survey (2004) showed that some changes took place in the beginning of this decade indicating that the proportion of intensively grazed salt marshes has dropped now to about 40% in the mainland areas and increased to about 20% on the islands.

The analysis revealed a high proportion of ungrazed salt marshes on the islands compared to the mainland (except for Schleswig-Holstein where the Halligen are exploited for livestock grazing). For The Netherlands, the high proportion can partly be attributed to the large area of green beaches.

The mainland salt marshes in The Netherlands have a high proportion of moderate use which reflects the grazing management of artificial salt marshes for nature conservation purposes aiming at high biodiversity.

7.3 Processes

Monitoring is important to record changes in very dynamic ecosystems such as salt marshes. In order to build a framework of ecological backgrounds in these dynamic systems, the QSR group will discuss some important features behind the changes. Moreover, the effects of sea level rise, changes in land use and maturation will be the core issues of salt marsh dynamics during the decades to come. For nature conservation interest in relation

to coastal defense it is important to define the type of landscape to be protected.

7.3.1 Natural development?

The discussion on the naturalness of salt marshes within the QSR group resulted in advanced insights concerning the target definition and has made it necessary to relate the habitat-related targets to the broader landscape scale. As a first step the group agreed to the following specification of the term 'natural vegetation' with regard to artificial salt marshes resulting from sedimentation fields (Target 3): 'The aim is a salt marsh vegetation diversity reflecting the geomorphological conditions of the habitat.' A second outcome of the discussion was the definition of naturalness on a landscape scale. The group defined two categories.

'Natural landscapes' feature a self-stimulated development and geomorphological conditions that are not affected by humans. They show a natural drainage system with meandering creeks and levees with higher elevation than the adjacent depressions. They have no erosion protection measures and are not used for coastal defense or agricultural purposes. They occur in sandy back-barrier conditions (e.g. Norderney, Spiekeroog, Mellum, Memmert, Scharhörn, Nigehörn, Trischen in Germany, Ameland, Schiermonnikoog in The Netherlands and Keldsand, Keldsand Vest and Langli in Denmark).

'Semi-natural landscapes' either feature a salt marsh within sedimentation fields and have a man-made drainage system by ditches or have an extensive wide-stretched natural creek system but are affected by measures to enhance livestock grazing or cutting. The latter are found on islands and in foreland clay marshes without sedimentation fields.

Characteristic salt marsh plant species can be present in all landscape types. However, their abundance in typical salt marsh vegetation types and their spatial arrangement in the vegetation structure can be affected by drainage, land use and management. The same is true for vegetation types.

Type of landscape	Geo-morphological conditions			Land use / management	Examples
	Drainage	Erosion protection	Sediment trapping		
Natural	creeks	none		none	Mellum, NDS, Ameland east, Schiermonnikoog east, NL
Semi-natural	a) natural creeks	a) none		none / grazing / cutting	Skallingen, DK
	b) ditches or revitalized creeks	b) groynes			Wurster Küste, Buscher Heller, NDS; Noard Fryslân Bütendyks, NL

Table 7.3:
Outline of the different landscape-types from natural to semi-natural landscape features and examples for land use and management.

Geomorphological conditions may change in the long term, i.e. decades, whereas the effects of changes in land use and management can occur within a few years. This hierarchical arrangement on a landscape level implies that changes in land use and management cannot result in, for example, a transition from semi-natural into a natural marsh as a landscape type but that the vegetation can develop without further human interference towards the specification of Target 3.

7.3.2 Effects on succession: ageing to climax

Because of the shifting of the seawall line towards the sea combined with the embankment of the bays in the past, natural sedimentation areas are missing in most parts of the coast today (Dijkema *et al.*, 2001). So the presence of seawalls as a landward boundary and of sedimentation fields as a seaward boundary reduces the dynamic character of salt marshes. The salt marshes in the sedimentation fields grow up in an unnatural high way, on the other side the sediment is missing in front of the sedimentation fields to build new lower salt marsh. In consequence this corset on the one hand may stabilize the marsh. On the other hand the policy of stabilization of the sedimentation fields may prevent a further seaward growth of the habitat. This may lead to an ageing of the vegetation. Ageing tends to result in an extension of mid and high-marsh communities at the expense of pioneer and low-marsh communities. Ageing of salt marshes is a recent focus in research (Esselink 2000; Bakker *et al.*, 2003a,b) and ageing was not a topic in the 1999 QSR. At both back-barrier sandy marshes and clayey mainland marshes succession may proceed towards a tall canopy of few species such as *Spartina anglica*, *Atriplex portulacoides*, *Elytrigia atherica*, *Elytrigia repens* and *Phragmites australis* at the lower and mid-high marsh, respectively. This succession can run faster in the absence of livestock grazing. This overall trend does not appear in every location and several examples – even on a large scale – indicate that the development does not always show the expected succession (Kiehl *et al.*, 2003; Bakker *et al.*, 2003a,b). Candidates to explain different successional pathways are inundation frequency, surface elevation change and cessation of grazing. Monitoring can give the answer.

Whether the vegetation diversity is reflected by the geomorphological conditions of the habitat (compare Target 3) during only a relatively short period of time (30–60 years) or whether it is a long-lasting relationship has neither been stud-

ied in detail nor is well understood. We thus do not know whether single species will dominate the entire zonation in the absence of livestock grazing or whether a process related to continuous interaction between the environment and the vegetation will lead to an ongoing rejuvenation in vegetation patterns as proposed in the mosaic cycle theory (e.g. Remmert, 1987). Temporarily die-back of *Atriplex portulacoides* after severe winters is well known (Beeftink *et al.*, 1978). Back-barrier marshes behind an artificial sand dike (e.g. on Terschelling) have a similar age all over the marsh. Hence they show ageing and lack the younger successional stages. The entire successional series of young, intermediate and old marshes can be seen on islands that extend eastward (NL: Schiermonnikoog, Ameland; eastern parts of the Niedersachsen islands Juist, Norderney, Langeoog, Spiekeroog; HH: Scharhörn, Nigehörn; SH: Trischen). At the long term rejuvenation of aged back-barrier marshes may take place by breaching the artificial sand dike or the natural dune ridge.

Recent studies (Bakker *et al.*, 2003a,b) revealed that grazing by small herbivores such as hares and geese has an impact on salt marsh vegetation, too. Hares can retard natural succession at back-barrier marshes for some decades, and hence facilitate conditions for geese, as shown by comparison at Schiermonnikoog with hares, and Rotterumerplaat and Mellum without hares (Kuijper and Bakker, 2003). Succession towards a uniform and tall canopy and with it the previously mentioned process of ageing can be prevented by large herbivores such as cattle and sheep or by increased water logging of the marsh. These measures facilitate for both hares and geese (e.g. Schiermonnikoog; Bakker *et al.*, 2003a,b; Leybucht; Bergmann *et al.*, 2003).

7.3.3 Effects of management on succession

The 1999 QSR drew attention to the achieved reduction in livestock grazing. Long-term and frequent monitoring in experimental sites on the effects of cessation of livestock grazing on succession reveals in previously exploited salt marshes a trend of increase of tall canopy. This has been shown at back-barrier marshes (Schiermonnikoog, Terschelling) (Bakker *et al.*, 2003a,b), foreland marshes with groynes (Netherlands coast, Leybucht and Sönke-Nissen-Koog, Germany) (Bakker *et al.*, 2003a,b), Halligen (Langeness) (Kleyer *et al.*, 2003), brackish marshes (Dollard) (Esselink, 2000) and de-embanked summer polders (Hauener

Hooge, Peasemarlannen) (Bakker *et al.*, 2002), thus mimicking the long-term succession at never exploited back-barrier marshes as could be found at the eastern points of Ameland (Eysink *et al.*, 2000), Schiermonnikoog, Terschelling (Bakker *et al.*, 2003a,b), Rottumerplaat, Mellum (Kuijper and Bakker, 2003) and Spiekeroog. Exceptions are marshes that have been excluded from livestock grazing during a period of less than 15 years, and sites with a very low rate of sedimentation and hence nitrogen input at a back-barrier marsh (Skallingen) (Bakker *et al.*, 2003a,b), or foreland marsh with groynes (locally Hamburger Hallig) (Schröder *et al.*, 2002). In semi-natural salt marshes, both heavy grazing (overall short canopy) and no grazing (overall tall canopy) show less structural variation than intermediate grazing (Friedrichskoog, Langeness, Leybucht, Groningen mainland coast) (e.g. Bakker *et al.*, 2003a,b; Esselink, 2000, Kiehl *et al.*, 2003; Kleyer *et al.*, 2003).

7.3.4 Effects of sea level rise

By a combination of natural sedimentation and perennial vegetation the elevation of salt marshes is able to follow a much increased rise in sea level compared to the current 0.25 cm/yr. Published figures are 5 mm/yr for barrier island marshes and 10 mm/yr for mainland marshes (Dijkema, 1997). Based on the monitoring of 17 years of soil subsidence due to the extraction of natural gas on the barrier island of Ameland even double figures seem possible for the marsh zones closest to the Wadden Sea (Eysink *et al.*, 2000). On the Groningen mainland coast local problems arose in the pioneer zone in front of the marsh, due, amongst other reasons, to soil subsidence (Slochteren gas extraction). A low vegetation cover, particularly of annual species, provided less protection of new sediment, with a subsequently lower net sedimentation. The effect was cliff erosion of the salt marsh, in other words the vertical accretion of the marsh zone, continued, but its area decreased due to lateral erosion. Brushwood groynes with a maximum fetch of 200 m solved the problem, preventing erosion by waves and currents and allowing free exchange of water with sediment to form a gradual transition from the intertidal flats to the marsh (Dijkema *et al.*, 2001).

In general, the natural salt marsh processes feature a knife cutting both ways in forming highly valuable nature and in a self-regulating protection in front of the seawalls, because the elevation of the marshes keeps pace with the increase in sea level and with soil subsidence. The threshold value for the intertidal flats seems to be a rela-

tive sea level rise of 0.6 cm/yr. Beyond this threshold intertidal flats start to disappear and even brushwood groynes will no longer be sufficient to maintain a pioneer zone and thus protect a salt marsh in that circumstances. Stone is an unattractive but simple alternative to protect the salt marsh zone at the most exposed parts under the strict precondition that all the creeks remain open to the Wadden Sea to allow free import of sediment. One more natural alternative practice is an increased nourishment with sand of the right grain size to the barriers, to the outer delta or even to the inner delta to allow more sand transport to the intertidal flats.

7.4. Salt marsh monitoring

The status of the Wadden Sea salt marshes has to be discussed in the framework of the trilateral salt marsh Targets and the EC Habitats Directive. A detailed monitoring program, as implemented within the TMAP and adjusted by the proposed vegetation typology is an essential pre-requisite to fulfill the normative requirements. The habitat types 1310 Salicornia and 1320 Spartina include the pioneer zone, whereas the remainder of the salt marsh habitats (low marsh, high marsh, sandy, green beach and brackish marsh) are included in a single habitat 1330 Atlantic salt meadows.

7.4.1 Salt marsh monitoring and trilateral Targets

The Targets of the Wadden Sea Plan include the issues of natural and artificial marshes, morphology, drainage, vegetation structure and zonation, as well as conditions for migrating and breeding birds. Within the TMAP Common Package, the following salt marsh parameters are monitored:

- location and area of salt marshes (every five years),
- vegetation types (every five years),
- information concerning land use/management at least every five years,
- information concerning geomorphology and artificial drainage of salt marshes (every five years).

The vegetation on salt marshes continuously changes as a result of natural succession, changes in drainage and sedimentation, and in land use and management such as abandoning, grazing, cutting. The changes will occur at various time scales: 1) changes in geomorphology such as levees/depressions and meandering creeks will take at least decades to happen; 2) some changes in the vegetation can occur in a relatively short peri-

Table 7.4:
Overview of available monitoring programs for salt marsh vegetation in the countries covering the whole area (GIS data based on aerial photographs and ground truth covering the whole Wadden Sea area).

Country	Time / Frequency	Level
The Netherlands	Every 5-7 years ¹⁾ since 1980	Vegetation and land use types
Niedersachsen	1991, 1997, 2002	Biotope and land use types
Hamburg	1995 Neuwerk	
	1998 Neuwerk (east), Scharhörn, Nigehörn	
Schleswig-Holstein	2004	Biotope and land use types
Denmark	1988 ²⁾ , 1996 ²⁾ , 2001/2002	Vegetation and land use types
	2000 ³⁾	Area, grazing intensity

1) rotating monitoring schedule of subareas with a frequency of 5-7 years (since 1980), VEGWAD-program, Ministry of Transport, Public Works and Water Management,

2) excluding Hallig marshes,

3) inventory of salt marshes: Ribe Amt, 2002: Strandenge i Ribe Amt – Status 2000.

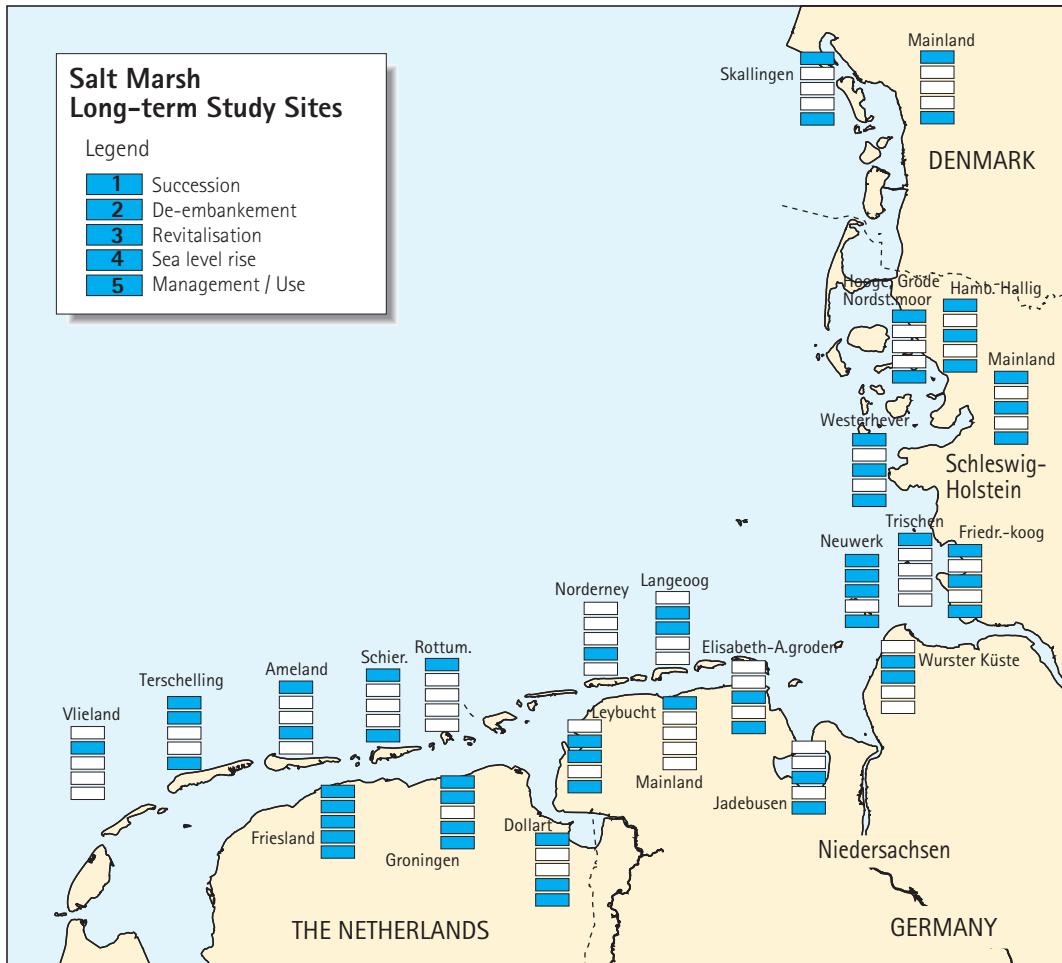
od of time, *i.e.* within a few years. Other changes take their time: once a threshold has surpassed after for instance 20 years, rapid changes have been recorded. The long-term changes will affect both the total area of the habitats and the area of the different zones. Short-term changes and year-to-year variation within the different vegetation types and abiotic conditions can only be monitored by annual recording of permanent plots.

Detailed current annual monitoring programs with respect to vegetation composition are indicated in Figure 7.8. In the near future a number of

these sites might be incorporated into the framework of International Long-Term Ecological Research sites (ILTER). In order to allow generalizations, such detailed monitoring programs may be carried out in at least three sites in each geomorphologic unit (see Table 7.1) in the Wadden Sea to underpin changes recorded every five years at the level of the entire Wadden Sea.

As a new development in monitoring of salt marshes in the Danish part of the Wadden Sea, a new national monitoring program was started in January 2004. This program, NOVANA, includes five

Figure 7.8:
Overview of long-term study sites in the Wadden Sea salt marshes.
1 = Succession:
Monitoring of sedimentation/erosion (tables, bars, leveling), permanent plots).
2 = De-embankment projects and studies.
3 = Revitalization: reduction of drainage, creek damming experiments, clay pits.
4 = Sealevel rise: subsidence experiments, tidal inundation.
5 = Management / use: grazing and cutting.



intensive and a larger number of extensive study sites (lower monitoring frequency) in Wadden Sea salt marshes. The intensive stations are going to be monitored every year and the extensive every sixth year. The NOVANA program for salt marshes includes vegetation analyses and management data for each of the 40 plots in each station.

Comprehensive information about the development of salt marsh vegetation and area for the whole Wadden Sea has been made available during the past decade from interpretation of aerial photographs combined with field mapping (Tab. 7.4) and from several long-term study sites (Figure 7.8).

Within the TMAP, a common trilateral classification scheme for the salt marshes has been developed. The classification is based on the SALT97 typology (de Jong *et al.*, 1998) and covers six salt marsh zones (pioneer zone, low marsh, high marsh, green beach, brackish marsh, fresh grassland).

Additionally, common criteria for areas with high and medium stocking rates for livestock grazing and no land use as well as for drainage intensity have been defined. Thus, for the first time, up-to-date trilateral salt marsh maps for different themes (zonation, grazing, drainage) could be made available covering the whole Wadden Sea to assess the implementation of the Wadden Sea Plan Targets.

This information can also be used as basic data for reporting under the Habitats and Water Framework Directives.

7.4.2 Salt marsh monitoring and EC Directives

The Habitats Directive groups the entire marsh into the habitat types 1310 Salicornia and 1320 Spartina (pioneer zone), whereas the remainder of the salt marsh habitats (low marsh, high marsh, sandy green beach and brackish marsh) are included in a single habitat, 1330 Atlantic salt meadows. The aim of the Habitats Directive is to 'maintain or restore, at a favorable conservation status, natural habitats and species of wild fauna and flora of Community interest'.

Vegetation zonation is not enough to define habitats and a favorable conservation status. Abiotic conditions such as inundation frequency trigger the vegetation, but the structure of the vegetation and the species composition also characterize habitats. A tall canopy of dominant plants affects the occurrence of smaller plants. The structure and species composition of plant communities affect animal populations such as birds and insects. The vegetation reflects the important zonation types, including pioneer zone, low marsh,

high marsh, green beach and brackish marsh, and human interference including drainage, groynes and land use. Hence, to fulfill the requirements of the Habitats Directive the landscape type as well as habitat features such as geomorphology, plant communities, vegetation structure and the functioning of the habitat with respect to animal life must be included.

In order to compare areas of different habitats and changes in habitats, a uniform vegetation classification for the entire Wadden Sea salt marshes is an indispensable tool. The TMAP salt marsh group thus has developed a detailed description of vegetation types covering the six salt marsh zones. This detailed key, comprising 31 vegetation types, is needed, for example, to find accurate answers about short-term and small-scale changes of the different vegetation types within the marsh, to describe long-term changes in area and place of vegetation types within the vegetation zones, to analyze the functioning of the vegetation with respect to animal life, especially between the habitat and vegetation requirements of certain bird species, such as the barnacle goose. Furthermore the detailed vegetation key is needed to analyze the development of single vegetation types, e.g. those belonging to 'Red Lists', and to allow a critical analysis of distribution patterns of the vegetation in relation to land use within and between countries. Zonation data can give the required answers.

Within the Water Framework Directive (WFD), salt marshes are grouped under the biological quality element 'angiosperms' for which a 'good ecological status' has to be reached by 2015. More detailed assessment criteria are currently being prepared within the WFD intercalibration process which will be completed by the end of 2006. The developed TMAP vegetation key can also be used as a basis for an assessment within the WFD.

7.5 Conclusions

a. Monitoring and data basis

Significant progress has been made since the 1999 QSR in compiling a comprehensive inventory of all salt marshes in the Wadden Sea based on detailed surveys and GIS data analysis. For Denmark recent surface data is still lacking. The data could be assessed based on harmonized criteria for salt marsh zones and land use including drainage and grazing. A more detailed vegetation analysis can now be carried out by using trilaterally harmonized criteria for vegetation types. This tool will allow a more consistent analysis of the salt marsh vegetation with regard to the Targets.

Salt marsh on Hallig
Langeness
(Photo: M. Stock)



b. Changes of salt marsh area

Although inconsistencies occur between the datasets from different areas and time periods and therefore exact figures cannot be given, an increase of the Wadden Sea salt marsh area has been observed in most areas during the past decades.

In The Netherlands and Germany, roughly 56% of the salt marshes on the islands, and roughly 7% of the salt marshes on the mainland have never been artificially drained and are not grazed by livestock and thus can be regarded as natural. In the Hamburg Wadden Sea, about 35% of the salt marshes have never been influenced by any land use or artificial drainage. For Danish salt marshes information on drainage is not available.

c. De-embankment

About 620 ha of salt marshes (240 Niedersachsen, 40 Hamburg and 340 in NL) have been de-embanked and the possible development of new salt marsh areas and vegetation development are being monitored.

d. Detailed information on land use

Since the 1980s, livestock grazing has generally decreased in the entire Wadden Sea area. A reduction of 50% of areas with intensive grazing could be observed on the mainland salt marshes in The Netherlands and Germany whereas in Denmark the situation has not changed much compared to the situation in 1987 (about 70% intensive grazing on the mainland). For the northern part (Ribe County) even an increase of the intensively grazed areas could be observed.

In about 39% of the mainland salt marshes, no drainage measures have been taken during the past 10 years. In about 60% of the island salt marshes there were no drainage measures at all,

and in an additional 31% of the island salt marshes no artificial drainage measures have been carried out during the past 10 years.

e. Ageing of salt marshes

Ageing to climax vegetation was observed in some parts of the Wadden Sea which led to the extension of mid and high-marsh communities at the expense of low-marsh communities on the mainland salt marshes in The Netherlands.

There may be a relation between rate of sedimentation, long-term cessation of grazing and the spread of single species such as *Spartina anglica*, *Atriplex prostrata*, *Elytrigia atherica*, *Elytrigia repens* and *Phragmites australis*.

f. Common data set for EC Directives

The proposed vegetation typology, in combination with the other already implemented TMAP parameters, is a pre-requisite to fulfill the requirements of describing the 'favorable conservation status' of the Habitats Directive and the 'good ecological status' of the Water Framework Directive.

7.5.1 Recommendations for monitoring and research

The TMAP Salt Marsh Workshops have further specified the TMAP guidelines for salt marsh monitoring as follows:

- Location and area of salt marshes can be derived from remote sensing without mapping of vegetation zones or vegetation types,
- Within the habitat 'salt marsh', vegetation types have to be monitored according to the guidelines. This should be based on the proposed classification system in Table 7.2. The classification allows harmonization of different ways of vegetation mapping in the triat-

eral Wadden Sea area (every five years). The specified vegetation classification (31 types) is sufficient to fulfill the requirements of the Habitats Directive.

- An aggregation of the vegetation types are the vegetation zones (pioneer, low, high, brackish marsh, green beach and fresh grassland).
- To assess the processes, 'vegetation types' should be monitored at several permanent sites on an annual basis in relation to surface elevation changes and management data (Figure 7.8).

Because the average frequency for mapping the complete area is 5–7 years, it may take 10–14 years before changes can be detected for the whole area. Therefore, additional long-term study sites with higher monitoring frequency are required. Long-term study sites are also necessary to understand salt marsh processes and new developments and to adapt monitoring and management. The results of the de-embankment projects (nine sites in the Wadden Sea with a total area of 620 ha of salt marshes, 240 ha Niedersachsen, 40 ha Hamburg and 340 ha in NL) and the results of cessation of drainage measures and new groynes have to be monitored during the coming years, as developments may take several years. In order to evaluate the results of de-embankments, criteria for success with respect to tidal amplitude, salinity, plant species, plant communities, animal groups need to be developed.

It is recommended that Denmark also should provide comparable data on zonation, grazing and drainage.

The Wadden Sea may be incorporated into the framework of the International Long-Term Ecological Research sites (ILTER) (wwwILTER.edu).

7.5.2 Recommendations for management

a. Increased area of natural salt marshes

It is recommended not to disturb the geomorphology of naturally developing marshes in such places nor as well as in front of sedimentation fields. Mainland salt marsh area is extremely low compared to historic references.

Increase of the area of (semi-)natural salt marshes may take place by breaching summer dikes or sand dikes protecting summer polders. Wherever possible this technique should be applied further. It is under discussion as to whether new marshes resulting from de-embankment may include man-made creek-systems and livestock grazing regime.

Rejuvenation of natural salt marshes on barrier islands can be done by removing the artificial sand dikes (and allowing wash-over processes to take place).

b. Increased natural morphology and dynamics of artificial salt marshes

Increase of natural geomorphology and dynamics of artificial marshes can be achieved by the cessation of drainage by ditches. Reduction or cessation of drainage by ditches in mainland marshes may locally result in more natural drainage patterns and increased water logging of the marsh with subsequent secondary pioneer vegetation, even within sedimentation fields. It also may result in the development of depressions and levees.

Reduction in artificial drainage accommodates the natural situation more and more and can lead to a secondary pioneer zone within marsh depressions. In sedimentation fields that have not yet been drained by ditches, meandering creeks may develop. It is recommended to stop artificial drainage in all marshes without any land use without affecting the drainage of dike foots. Dug clay pits (as long as they remain separated from the intertidal flats) can show a sedimentation and development of a natural drainage pattern, dependent on their position and their connection to an existing creek system (Metzing and Gerlach, 2003).

c. An improved natural vegetation structure, including the pioneer zone, of artificial salt marshes

It is recommended to specify Target 3 on 'natural vegetation structure' of artificial salt marshes as follows: 'The aim is a salt marsh vegetation diversity reflecting the geomorphological conditions of the habitat'.

Improved natural vegetation structure in artificial marshes reflecting geomorphological patterns can be reached by cessation of drainage in lower sedimentation fields.

On existing salt marshes with a high rate of sedimentation, ageing may result in monotonous climax vegetation without livestock grazing. Differences in geomorphology will be masked by such a homogeneous vegetation. In such marshes moderate grazing may result in high variation of the vegetation structure, if this is the aim. In marshes with a low rate of sedimentation (1–3 mm/year) a diverse vegetation structure may develop on its own.

Reduction or cessation of drainage by ditches in mainland marshes may locally result in more natural drainage patterns and increased water log-

ging of the marsh with subsequent secondary pioneer vegetation, even within sedimentation fields.

Whether livestock grazing regimes will be applied clearly depends on the target settings for certain areas. Within national parks a vegetation development in relation to the geomorphological structure of the habitat is the aim. There is no definite aim for a certain composition of flora or fauna. Even within the artificial 'sedimentation field' the habitat should develop by its own and without further human interference. In some areas, e.g. outside the national parks, a management

regime aiming at favorable conditions for migrating and breeding birds via livestock grazing may be applied. In The Netherlands and Denmark, livestock grazing is part of salt marsh management to prevent ageing of salt marshes.

d. Favorable conditions for birds

Management of salt marshes can be a tool to achieve favorable conservation status for birds. Detailed recommendations can be found in chapter 12.

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8. Tidal Area



(Photo: K. Janke)

The Tidal Area covers all tidal flats (the littoral) and subtidal areas (the sublittoral). The seaward delimitation of the Tidal Area is formed by lines connecting the tips of the outer Wadden Sea islands. The landward delimitation is the pioneer zone of the salt marshes in front of the mainland, or, where salt marshes are not present, the mean high water level at spring tides. In estuaries, the upper limit is formed by the mean 10 psu isohaline at high water in the winter situation.

8.1 Hydrology – Geomorphology

Karel Essink

North Frisian islands,
Halligen and sand banks
(Satellite image:
Brockmann Consult).



8.1.1 Introduction

The Tidal Area and the Offshore Area form a coherent system. There is intensive water exchange through the tidal inlets between the islands. Sea level rise causes sand to be transported from the foreshore of the islands and the seabed in the Offshore Area to the Wadden Sea (see chapter 3 'Climate'). Since historic times this has caused the islands to migrate in the direction of the mainland. Before the mainland coast was fixed by dikes, the coastline reacted to such sea level rise by receding. Since dike building started, the Wadden Sea was progressively squeezed between these fixed sea dikes and the landward migrating islands (e.g., Flemming and Davis, 1994; Mai and Bartholomä, 2000).

Target

An increased area of geomorphologically and biologically undisturbed tidal flats and subtidal areas.

In the 1999 QSR the effects of this coastal squeeze on the geomorphology of the Wadden Sea were not described, notwithstanding two directly related Targets. Furthermore, continued deepening of shipping channels in estuaries may lead to hydrological and geomorphological changes. Little has been documented so far for the estuaries in the Wadden Sea.

8.1.2 Coastal squeeze

The most important cause of coastal squeeze in the Wadden Sea, undoubtedly, is the long-term

land reclamation by successive endikement of salt marshes and embayments. The historic loss of salt marshes since 1600 in the Dutch Wadden Sea was documented by Dijkema (1987). Reconstructions of historic coastlines of the Niedersachsen Wadden Sea show that 58% of potentially available tidal mud flats have disappeared (Delafontaine et al., 2000). Along the Dutch coast of the Wadden Sea even larger areas have been lost, compared to hardly any loss along the Danish coast because of the elevated Pleistocene grounds directly bordering the Wadden Sea (cf. Mai and Bartholomä, 2000). As the Wadden Sea between the mainland and the islands narrowed, concomitant changes occurred in sediment type distribution typically showing lower grain size close to the mainland coast as a consequence of settling velocity gradients over the tidal flats between island and mainland (Figure 9 in Mai and Bartholomä, 2000). In the course of sea level rise, especially after dike building and land reclamation had begun, these settling velocity gradients have changed, allowing less mud to be deposited near the mainland coast, resulting a general depletion of fine-grained material (Dellwig et al., 2000). Continued sea level rise will lead to a further depletion of fine-grained sediment and organic matter, and may eventually lead to the complete disappearance of tidal flats (see the model in Flemming and Nyandwi, 1994).

These fine-grained, organically rich sediments are assumed to play an important role in the recruitment success of bivalves (see chapter 8.2).

As a combined result of sea level rise and man-

made fixing of the mainland coast by dikes and successive endikements and land reclamations, the space between the islands and the mainland coast has become narrower (coastal squeeze). This has resulted in loss of mud flats along the mainland coast, which are important as a settling habitat for juvenile bivalves.

This loss of fine-grained sediment is considered a deviation from the natural dynamics in geomorphology because it has been caused by progressive endikement and land reclamation. Moreover, there is a deviation from the targets 'natural dynamic situation' and 'increased area of geomorphologically undisturbed tidal flats'.

8.1.3 Tidal regime and geomorphology of estuaries

Deepening of tidal channels in estuaries to promote shipping to sea ports that are located at a distance from the mouth of the estuary causes hydraulic changes. High water levels tend to become higher, and low water levels to become lower, as shown for the Ems, Weser and Elbe by Jensen *et al.* (2003). Hydraulic changes, however, do not stand alone. Increased deepening of the shipping channels to the port of Antwerp (Belgium) has changed the geomorphology of the Western

Scheldt, causing significant losses of salt marsh, intertidal mudflats and shallow water, particularly in the eastern part (e.g., Huys, 1995; Vroon *et al.*, 1997).

It is not fully known to what extent the progressive deepening of the estuaries of the Ems, Weser and Elbe has caused changes in the geomorphology similar to those described for the Western Scheldt.

Effects on the intertidal geomorphology in the Grådyb tidal basin of deepening the shipping channel to the harbour of Esbjerg by 4 m in 1993 have been very small and hardly measurable (Pejrup *et al.*, 1993).

8.1.4 Recommendations

- The changes in distribution of high mudflats should be followed more precisely, especially in areas with relatively recent land reclamations/endikements, because of their importance as settling habitat for juvenile bivalves.
- A study should be made to provide insight in the effects of progressive deepening by dredging on estuarine geomorphology and consequently on the ecological functions of estuaries in the Wadden Sea.

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8.2 Macrozoobenthos

Karel Essink

(Photo: M. Stock)



8.2.1 Introduction

In the 1999 QSR, an account was given of the development of three immigrant bivalve species. An update on these and other introduced species is given in chapter 6 of this report.

Also in the 1999 QSR, an attempt was made to clarify the possible causes of long-term changes in total biomass of the intertidal macrozoobenthic community as measured at selected monitoring locations within the Wadden Sea. Severity of winter and eutrophic conditions were mentioned as major regulating factors. In addition, the possible negative effects of mechanized shellfish fisheries were briefly introduced. The present chapter presents an update based on TMAP monitoring data and recently published information. New data on immigrant species (e.g. *Ensis americanus*, *Marenzelleria* cf. *viridis*, *Crassostrea gigas*) is presented in chapter 6 'Introduced species'.

Target

An increased area of geomorphologically and biologically undisturbed tidal flats and subtidal areas.

No trilateral Target was developed with respect to macrozoobenthos of soft sediments in the Tidal Area of the Wadden Sea. However, the general Target of 'an increased area of geomorphologically and biologically undisturbed tidal flats and subtidal areas' applies.

8.2.2 Recruitment, distribution and winter character

During cold winters, higher proportions of young (~5 mm shell length) bivalve *Macoma balthica* migrate from high coastal flats to low and/or offshore areas than in mild winters. This phenomenon, documented as early as the 1980s, was reaffirmed by new evidence obtained in different parts of the Dutch Wadden Sea (Beukema and Dekker, 2003; Hiddink and Wolff, 2002). This causes a redistribution of *Macoma balthica* over the different depth zones of the Wadden Sea and the offshore area, and needs to be taken into account when analyzing long-term data sets of macrozoobenthos from stations either in the littoral or the sublittoral parts of the Wadden Sea.

Another effect of cold winters is that the reproduction success of bivalves in the subsequent summer is usually better than after mild winters. This already known phenomenon was further investigated, both experimentally and through analyzing long-term data sets (Beukema *et al.*, 2001; Philippart *et al.*, 2003; Strasser *et al.*, 2001, 2002). In *Macoma balthica*, mild winters cause low egg production. Survival of post-larvae during the first few months of benthic life, however, plays a more prominent role in the recruitment process (Beukema *et al.*, 1998). At the tidal flats of the Wadden Sea and other shallow coastal waters bivalve spat is eaten by both shrimps and shore crabs. This predation pressure substantially reduces numbers of bivalve spat (Flach, 2003; Hiddink *et al.*, 2002; Strasser, 2002). After a severe winter, predators

such as the shore crab may return to the Wadden Sea too late to effectively prey upon bivalve spat, thus enabling a good recruitment (Strasser and Günther, 2001). Recruitment failures in the cockle (*Cerastoderma edule*), sandgaper (*Mya arenaria*) and Baltic tellin (*Macoma balthica*) were more frequent during the last approximately 15 years, especially at lower intertidal levels, and were negatively correlated to the quantities of shrimps present at the time of settlement of bivalve post-larvae (Beukema and Dekker, 2005). Such a relationship was not found for recruitment at higher intertidal levels, where shrimp abundance is low.

This difference in recruitment success between lower and higher intertidal flats is explained mainly by differential predation pressure on post-larvae with these high flats serving as a refuge in years of high predator abundances, although at the same time the sediment at the lower flats tended to become coarser (Beukema and Dekker, 2004). As a consequence, the centers of distribution of the three bivalve species were found to shift to higher intertidal levels with muddier sediments. Such a change in distribution at a local scale (Balgzand, Groninger Wad) was found for cockle beds also on the scale of the entire Dutch Wadden Sea (Anon., 2003; Zwarts *et al.*, 2003). Changes in sediment composition may have been caused by the large scale disappearance of blue mussel beds (*Mytilus edulis*) from the intertidal flats of the Dutch Wadden Sea in 1990 due to a combination of prolonged recruitment failure and intensive shellfish fishery (Dankers *et al.*, 2003). Mussel beds cause increased contents of mud and organic matter in the surrounding sediments up to a distance of about one km (Kröncke, 1996; Zwarts, 2003). Intertidal mussel beds started to reappear in 1995, but are still largely absent from the western part of the Dutch Wadden Sea (Anon., 2003; Dankers *et al.*, 2003) making the most sandy sediments unsuitable for successful recruitment of cockles (Beukema and Dekker, 2004).

After a severe winter, recruitment success in three bivalve species was found to be different between the northern (north of Eiderstedt) and southern (west of the Jade Bay) Wadden Sea (Strasser *et al.*, 2002). These regional differences may be related to the different topography (orientation of islands and tidal inlets) and related differential effects of wind induced currents on bivalve recruitment, and/or to differences in parent stocks, larval supply or epibenthic predation.

In the shallow subtidal (10-20 m depth) of the offshore area of the Wadden Sea synchronous winter effects have already been described by Beu-

kema *et al.* (1988). For the Norderney area Kröncke *et al.* (2001) report significant effects of cold winters on benthic community structure. Moreover, a clear shift has become noticeable since 1988, when climatic conditions were different as indicated by higher values of the North Atlantic Oscillation Index (NAOI). High NAOI values are accompanied by effects including higher seawater temperatures, particularly in winter and spring. For the Sylt area, Armonies *et al.* (2001) suggest that the slow recovery after severe winters, which are often characterized by long spells of easterly winds, may also be caused by loss of larvae and juveniles drifting away to deeper North Sea waters.

A more extensive overview of the effects of climate change is given in chapter 3 'Climate'.

8.2.3 Effects of shellfish fisheries

The apparently decreased suitability of lower and sandy flats in the Dutch Wadden Sea to support bivalve recruitment described above could not unequivocally be attributed to bottom disturbing activities of fisheries for cockles, blue mussels or lugworms (Beukema and Dekker, 2004; Zwarts *et al.*, 2003). A long-term experimental study to verify or disprove the assumed negative impact of cockle fisheries through changes in sediment composition on bivalve recruitment (see Piersma *et al.*, 2001) was not undertaken as part of the EVA-II project evaluating the effects of shellfish fisheries. A longer lasting negative effect of cockle dredging on bivalve recruitment was only found in sediments with low mud contents (Piersma *et al.*, 2001) and was absent in an area with higher mud contents (Hiddink, 2003). In the final scientific report on the effects of Dutch shellfish fishery the results described below are presented (Ens *et al.*, 2004)

During the past ten years, cockle dredges touched each year on average 25% of the surface area of the cockle beds present in areas open to cockle fishery. This resulted in an ever-increasing proportion of the adult cockle stock being found in the areas closed for shellfish fishing. Cockle fishery caused considerable direct mortality (up to tens of percent) of shallow living non-target benthic fauna and also removed dispersed blue mussels from the tidal flats.

On a small spatial scale, cockle fishery caused a decrease in recruitment success of blue mussels. On the scale of the Dutch Wadden Sea, however, there is no evidence of such an effect. In the areas open to cockle fishery, fewer cockle spat per m² recruited than in the closed areas. This difference had disappeared by 2000; since then mean

recruitment density of cockles has even been slightly higher in the open than in the closed areas. This may be explained by a negative effect of high adult cockle densities on recruitment (cf. Beukema and Cadée, 1999) and by the fact that high densities of adult cockles increasingly occurred in the areas closed for fishing.

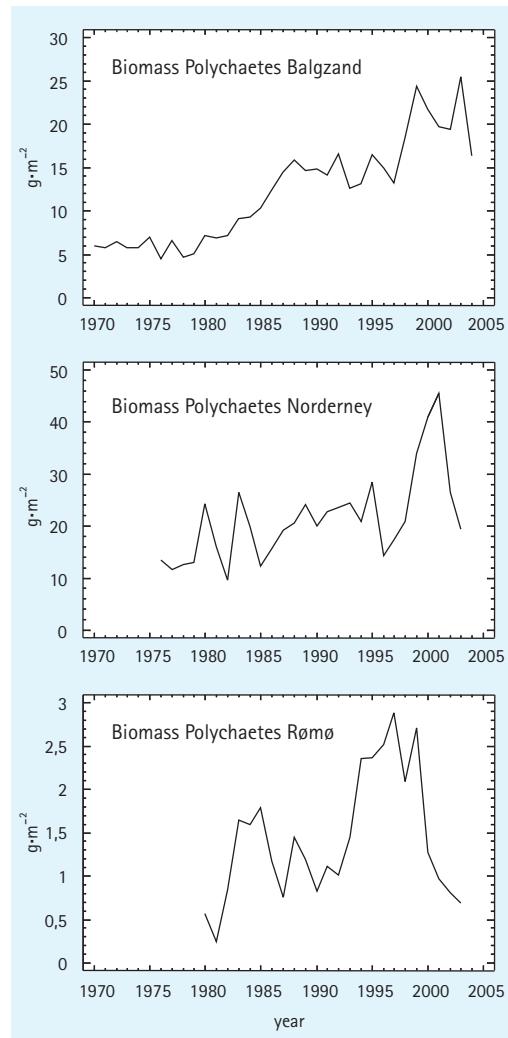
Effects of shellfish fishery on mussel beds will be treated in chapters 8.3 'Intertidal blue mussel beds' and 8.5.2 'Subtidal blue mussel beds'.

8.2.4 Eutrophication

In the 1999 QSR it was concluded that differences in eutrophic states within the Wadden Sea are not clearly reflected in differences in biomass of intertidal macrozoobenthos. A consistently increasing trend in biomass of polychaetes could not be related to nutrient input data (Essink *et al.*, 1998). This may partly be due to limitations of the data sets.

In a recent analysis of their long-term data sets

Figure 8.2.1:
Development of annual mean biomass (gram ash-free dry weight m^{-2}) of polychaetous worms at intertidal flats in different parts of the Wadden Sea.
Note: Danish data (Rømø) refers to 4 species only, *viz.*
Arenicola marina,
Heteromastus filiformis,
Nereis diversicolor and
Scoloplos armiger.



on phytoplankton, chlorophyll and intertidal macrozoobenthos in the Marsdiep-Balgzand area, Beukema *et al.* (2002) made comparisons between three decades, *viz.* the 1970s, 1980s and 1990s. It was around 1980 that a sudden and persistent increase occurred of phytoplankton cells, chlorophyll and of densities and biomass of zoobenthos, showing, however, considerable year-to-year variability. Their analyses show a significant positive correlation between chlorophyll concentration and density and biomass of zoobenthos, especially at places with already high biomass values. Apparently, here food supply was strongly limiting. In addition, the response to changes in phytoplankton food supply was strong only in suspension and deposit feeders, *i.e.* functional groups directly dependent on algal food, not in carnivorous species. Smaller polychaetes in particular became very abundant during the 1980s and 1990s. These developments indicate that not only the western Dutch Wadden Sea, but probably the entire Wadden Sea has been in an early stage of eutrophication (cf. Gray, 1992) during the last two decades. Any further development of eutrophication was probably prevented by environmental conditions such as strong tidal mixing preventing anoxia (e.g. 'black spots'), and severe winters as overriding regulators of zoobenthos abundance and biomass. In the Danish Wadden Sea no zoobenthos mass kills due to eutrophication related oxygen depletion were observed (Ærtebjerg *et al.*, 2003). In other parts of the Wadden Sea, such large-scale kills have been rare.

8.2.5 Are polychaetous worms taking over?

In the 1999 QSR, a consistently increasing trend in biomass of polychaetes in part of the Wadden Sea could not be related to nutrient input data. Data collected within the TMAP shows that the increasing trend in biomass of polychaetous worms for intertidal flat locations in the Dutch (Balgzand) and Niedersachsen (Norderney) Wadden Sea continued until 2004 (Fig 8.2.1) and also on parts of the locations monitored at Groningen intertidal flats. In the 1999 QSR, no such increasing trend was observed in the Danish Wadden Sea. After an update with recent data, there is still no significant trend (Figure 8.2.1). It must be noted that the Danish data refers to four polychaete species only, and not to all polychaetes present in the samples, which explains the low biomass values as compared with those present in other parts of the Wadden Sea.

Reise (1982) was the first to signal this increasing trend of polychaetes. He argued that the trend might have started even before the onset of eutrophication in the Wadden Sea, but could not give a clue as to the cause. Beukema *et al.* (2002) reported that at Balgzand intertidal flats (western Dutch Wadden Sea) small-sized worms became very abundant during the 1980s and 1990s. In the Dutch EVA-II project evaluating the effects of shellfish fisheries, it was hypothesized that bottom disturbance by cockle dredging favors the development of polychaetes. Extensive data collected provided indications that the densities of the ragworm *Nereis diversicolor* may have increased as a result of cockle fishery, but did not allow for clear conclusions (Anon., 2003). Finally, one might think of a process in which worms, generally having a r-type life strategy (relatively short-lived, regular reproduction), are developing whereas the K-type strategist bivalves (long-lived, irregular reproduction) are declining. Whether there is a causal or even a feedback relationship remains to be resolved. Perhaps we are facing a change of alternate stable states within the benthic system of the Wadden Sea (cf. van de Koppel *et al.*, 2001).

An explanation of the difference in trend of polychaete biomass between the northern (Denmark) and southern (Niedersachsen, The Netherlands) Wadden Sea cannot be easily presented. A difference in organic matter cycling processes between these major regions of the Wadden Sea, as suggested in chapter 5 'Eutrophication', might be a possibility. Further research into the possibility of having two sub-systems within the Wadden Sea is needed.

8.2.6 Are isolated populations endangered?

Most species occurring in the Wadden Sea belong to populations with a large geographical expansion along the western European coasts, e.g. *Mytilus edulis*, *Macoma balthica* and *Arenicola marina*. These populations have low genetic differentiation, typical of the absence of any kind of geographical isolation (Hummel, 2003). There are, however, several species with a disjunct distribution. One example is the lagoon cockle (*Cerastoderma lamarckii*) of which small populations have been observed in salt-marsh habitats at the island of Texel and Schiermonnikoog (The Netherlands) (Kuiper, 2000) and in salt-marsh creeks, ditches and brackish ponds in the northern Wadden Sea (Germany/Denmark) (Reise, 2003). The lagoon cockle has apparently disappeared from the intertidal zone of the northern Wadden Sea around



Eroded sediment showing tubes of *Lanice conchilega* (Photo: K. Reise).

1980, whereas it occurred at several sites in the 1960s and 1970s; it survived the severe winter of 1978/79 which killed almost all intertidal cockles (*Cerastoderma edule*). Seagrass beds in the upper intertidal were the preferred habitat, also connecting scattered occurrences in salt marsh ditches, creeks and ponds. The disappearance of these seagrass occurrences after 1980, together with increased storm surge frequencies (Hofstede, 1999) may have caused the lagoon cockle to vanish from the upper intertidal, leaving refuge only in sheltered salt marsh habitats (Reise, 2003).

Several species, such as the gastropods *Phytia myosotis*, *Alderia modesta* and *Hydrobia ventrosa*, the bivalve *Abra tenuis* and the isopod *Cyathura carinata* (see Reise, 2003), have disjunct distribution patterns, with isolated populations occurring in estuaries and lagoons. Little is known about the dispersal potential of these species and, therefore, of the risk of extinction of these populations. Presence or absence of these populations may play an important role in the assessment of ecological quality of coastal and transitional waters under the Water Framework Directive.



Nereis diversicolor (Photo: K.-E. Heers).

8.2.7 Conclusions

The observed decline in bivalve recruitment success over the last approximately 15 years, which is accompanied by a shoreward shift of their centres of distribution, may be explained largely by increasing predation pressure on the newly settled post-larvae by shrimps and shore crabs. This effect is clearest at lower intertidal levels, has been observed in different parts of the Wadden Sea and coincides with the occurrence of mild winters. This indicates the power of climatic factors in governing recruitment, and therefore population sizes of bivalves in the Wadden Sea. Continued global warming will therefore cause a declining trend of bivalve stocks.

On a more regional scale, however, deterioration of sedimentary conditions may play a role, especially on the more sandy lower tidal flats. Possible causes are the removal of mussel beds by fishery and sediment disturbance by cockle dredging. Mechanised fishery for cockles in the Dutch Wadden Sea had negative effects on recruitment of cockles and non-target species living in intertidal flats. There is an indication that the ragworm *Nereis diversicolor* and other small worms have increased in abundance.

It is concluded that during the last two decades the Wadden Sea has been in an early stage of eutrophication, almost without the occurrence of harmful anoxia except under patches of green algae. In the intertidal flats in The Netherlands and

Niedersachsen, biomass of polychaetous worms has continued to increase. Such a trend was not observed in the Danish Wadden Sea, with this restriction, however, that biomass data was not available for all worm species. Trends in polychaete biomass cannot be related to nutrient input data. The difference in trends between southern and Danish Wadden Sea may be related to supposed differences in organic matter cycling processes.

Isolated populations of benthic invertebrates in estuarine and brackish habitats may be endangered. These populations need further attention in order to elucidate their status.

8.2.8 Target evaluation

There is evidence of a loss of undisturbed tidal flat areas as a settling habitat for juvenile bivalves due to, for example, coarsening of the sediment.

Estuarine and brackish habitats, currently giving refuge to isolated invertebrate populations, seem too small to safeguard these populations.

8.2.9 Recommendations

- Further research into shifting centres of bivalve recruitment and their causes;
- Elucidation of the status of isolated estuarine and brackish invertebrate populations;
- Find an explanation for observed trends in polychaete biomass, and the differences in these trends within the Wadden Sea.

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8.3 Intertidal Blue Mussel Beds

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Blue mussel bed
 (Photo: G. Millat)



8.3.1 Introduction

Beds of the blue mussel (*Mytilus edulis*) are important biogenic structures in the Wadden Sea ecosystem, serving as habitat and as food source for a number of species. In the Wadden Sea Plan (1997), a specific trilateral Target was formulated aiming for an increase of the total area and a more natural development and distribution of natural intertidal mussel beds, providing a framework for habitat management.

Targets

- A natural dynamic situation in the Tidal Area.
- An increased area of geomorphologically and biologically undisturbed tidal flats and subtidal areas.
- An increased area of, and a more natural distribution and development of natural mussel beds, *Sabellaria* reefs and *Zostera* fields.

To protect intertidal mussel beds, in all three countries considerable parts of the intertidal area have been permanently closed for blue mussel fishing, but differences between countries are substantial. In The Netherlands, fishery is restricted to young, unstable beds outside areas that are permanently closed. In Niedersachsen, fishery of seed mussels is allowed in significant parts of the intertidal, in accordance with a management plan. In Schleswig-Holstein, mussel fishery is not allowed in the intertidal area, as well as, in most subtidal parts of the national park core zone. In

Denmark, mussel fishery is allowed on a small scale, in intertidal as well subtidal areas, but the quotas since 1992 have been fished in subtidal areas only. A comprehensive overview of mussel fishing policies was drawn up by the Common Wadden Sea Secretariat (CWSS, 2002a) (see chapter 2.5).

The Governmental Conference in Esbjerg (2001) acknowledged 'the efforts that have been made with regard to the policy on the mussel fishery' and stressed 'that the implementation of the Targets on geomorphology, eelgrass beds and mussel beds still deserves attention and, therefore decided 'to evaluate before the end of 2004 the mussel fishery with special attention to stable mussel beds' (§9 Esbjerg Declaration) and 'to base the conservation and management of mussel beds on the protection of sites where stable beds occur and areas with a high potential for the development of stable mussel beds' (§10 Esbjerg Declaration).

The 1999 QSR focused on a description of the long-term development of intertidal mussel beds up to 1997. In the 1980s and 1990s, the area of beds and biomass were lower than before 1980. Therefore, it was concluded that the Target of an increased area and a more natural development of natural intertidal mussel beds had not been reached. In fact, the number and size of mature blue mussel beds had declined in the last decade.

Several factors relevant for survival of mussel beds were discussed. It was doubted whether an increase in storminess (as observed in some parts

of the Wadden Sea during the last decade) or ice-scouring (no significant differences with the long-term average) had been the main factors of the observed long-term decline. Fisheries, on the other hand, had caused large declines and prevented recovery, especially in periods of failing spatfall. Therefore, it was proposed that the management of mussel fishery should be based on protection of sites where stable beds occur and of sites with a high potential for the development of stable beds.

The following paragraphs report on the implementation of the recommendations in the 1999 QSR, the developments of the mussel beds and mussel stocks since 1999, the impact of mussel fishery, and the role of bio-invaders in mussel beds.

8.3.2 Implementation of 1999 recommendations

8.3.2.1 A protocol for harmonized description and area measurement of mussel beds

In 2002, a common trilateral definition of a mussel bed was developed (CWSS, 2002b; Herlyn, 2005). This definition is based on the structure of mussel beds:

'A mussel bed is a benthic community structured by blue mussels. It may consist of a spatially well-defined irregular collection of more or less protruding smaller beds, which may be called patches, separated by open spaces. This description also includes young beds with a high abundance of small mussels. The described structure may not be so distinct in young beds or just settled beds (spatfall)!'

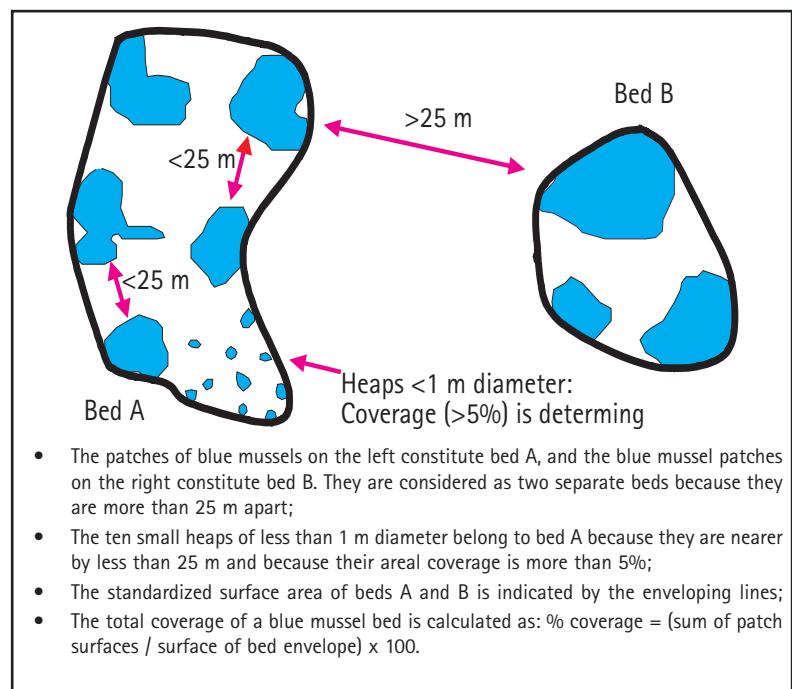
In the field, boundaries between a mussel bed and the surrounding intertidal flat are not always clear-cut, which can easily lead to differences in size estimates among individual observers. Moreover, in the field, transition zones between mussel beds and the surrounding tidal flat do occur. The following criteria were developed in order to make standardized decisions on the boundaries of mussel beds when carrying out field surveys (see also Figure 8.3.1): A group of mussel patches less than 25 meters apart is considered as a bed, but only if at least 5% of the sea bottom is covered by these patches; the coverage of the area with mussel patches is >5% if the space between them is (on average) less than about four times the patch diameter. These criteria have been used since 2002.

Fields of scattered mussels are not included in the definition of mussel beds and consequently they are not included in the quality status judge-

ment. These fields consist of individual and small conglomerates of mussels, often with some cockle shells attached to their byssus threads. They can originate from spatfall or from mussel beds that have been damaged by storms and can be transported over tens, hundreds or even thousands of meters. They are generally not able to form a sizeable biogenic structure, but fields of scattered mussel clumps may consolidate to mussel beds by spatfall or by more mussels being transported from other intertidal or subtidal locations to these areas. However, most scattered mussel clumps disappear within one or two years. That does not alter the fact that they may form an important food source for oystercatchers and gulls.

Aerial photographs and ground-surveys are used to determine the location, size and shape of mussel beds. For recognition of intertidal mussel beds on aerial photographs a stereoscope should be used. For monitoring purposes, it is important to carry out photographic surveys in a well-defined period of the year, because the surface covered by mussel beds can increase through spatfall during the summer months and will often decrease during autumn and winter due to storms and/or ice-scour. A relatively stable period is between March and July, after the winter and before new recruits can be detected on aerial photographs. Most of the maps of Dijkema (1989) were drawn from aerial photographs from this period. In The Netherlands (Ens *et al.*, 2004) and Niedersachsen (Herlyn and Millat, 2004), this period is recommended for aerial surveys of the sur-

Figure 8.3.1:
Blue mussel bed measuring protocol, with mussel patches (blue) and envelope (black).



face covered with mussel beds. In Schleswig-Holstein aerial photographs are intentionally made in autumn and therefore potentially include new spatfall of the year.

8.3.2.2 The protection of young mussel beds

In general, only limited research has been done on how and where young mussel beds could be best protected.

In The Netherlands, habitat modeling was used to predict the stability of newly formed mussel beds in the intertidal (Brinkman and Bult, 2002). In areas with a high potential for stable mussel beds according to the habitat model, relatively more newly formed mussel beds appeared than in other areas, indicating the usefulness of this habitat modeling approach. Since 1995, all mussel beds in these 'high potential' areas have been protected. An index was developed for judging the expected stability of present beds, taking into account parameters such as sediment stability, and density and age composition of the mussels in the bed (Brinkman *et al.*, 2003).

In Niedersachsen, all the sites of mussel beds recorded during the last 50 years were documented

in 1996 (Millat and Herlyn, 1999). The number amounted to 187 sites, of which 31 were protected by the National Park Law. From 1999 to 2003 17 additional sites were closed for fishery according to the 'Miesmuschelmanagementplan'. Additional data sets since then demonstrate that most of the blue mussel sites have shown a continuous occurrence of mussel beds. After an intensive revision in 2003, 102 sites were considered as locations where stable beds can occur (so called stable sites) (Herlyn and Millat, 2004). Under the new blue mussel fishery management plan (2004–2008), 17 out of these 102 sites are protected in addition to the 12 sites in areas closed for mussel fishery by the National Park Law.

In Schleswig-Holstein, all intertidal mussel beds, existing as well as new ones, have been protected since 1996.

In Denmark, some fishery was allowed until 2003. It was only allowed to take a part of the expected production of the standing stock each year. This approach is intended to keep the standing stock at a stable level over the years. If, for one reason or another, the standing stock falls to a lower level, the production will also decrease. The share to be reserved for the birds, however, will remain the same and the fishery will be given a lower quota for the following season (Kristensen, 1997, 2003; Munch-Petersen and Kristensen, 2001). During the last 15 years, annually 10,000–15,000 t of mussels have been protected to serve as food for birds, leaving 3,000–10,000 t for fishery.

In Denmark, the mussel fishery is restricted to harvesting of mussels of marketable size. The Danish regulations do not discriminate between intertidal and subtidal beds. This has been the precept since the beginning of the 1980s. Since 1992, mussel fishery has been allowed only in approx. 50% of the Danish Wadden Sea, the main fishing area being Ho Bugt and northern part of Lister Deep. These areas contain intertidal as well as subtidal beds, the latter being preferred by the fishermen. As a consequence, the intertidal beds in the Danish Wadden Sea have not been fished since 1992.

8.3.3 Development of area, biomass and age composition since 1999

8.3.3.1 The Netherlands

In their evaluation of the historical development of intertidal mussel beds, Dankers *et al.* (2003) re-estimated the area of mussel beds in the period 1960–1990. This area may have varied between 1,000 and 6,000 ha. The value of 4,120 ha for

Definitions

Mussel bed

A mussel bed is a benthic community structured by blue mussels. It may consist of a spatially well defined irregular collection of more or less protruding smaller beds, which may be called patches, separated by open spaces. This description also includes young beds with a high abundance of small mussels. The described structure may not be so distinct in young beds or just settled beds (spatfall) (Blue mussel workshop, 2002).

Stable bed

Bed where the structure (patches, formed relief) is clearly recognizable over many years (Blue mussel workshop 2003, QSR 1999).

Stable site

Location where mature mussel beds (one or more) occur regularly over several years (Blue mussel workshop 2002).

Assessment criteria for persistence of a mussel bed

Age of bed, type of location, sediment structure of mussel bed basis (Blue mussel workshop 2002).

Larvae settlement

The first benthic migrating stage of blue mussel larvae smaller than 1 mm is defined as primary settlement. The larvae can settle several times on various substrates until they get larger and settle more permanently on structures such as existing mussel beds or stones (secondary settlement) (Blue mussel workshop, 2000).

Spatfall

Settlement of young mussels on a tidal flat. These small mussels are called 'spat' during the year of settlement only.

Recruitment

The addition of young mussels to the reproducing population. For blue mussels, the concept of recruitment is used for young mussels which survived the winter (age = 1 year).

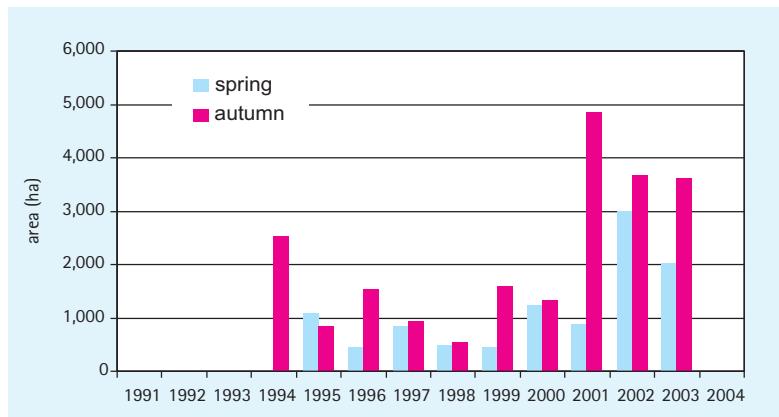


Figure 8.3.2: Surface area (ha) of intertidal mussel beds in the Dutch Wadden Sea since 1994. Data is achieved during a ground survey and reconstructed afterwards (Steenbergen *et al.*, 2003b).

An update of the reconstruction was made in November 2004, and thus the data shown can be slightly different from data in Steenbergen *et al.* (2003b).

1976 and 1978, presented in the 1999 QSR and well documented in the habitat maps for the Wadden Sea (Dijkema, 1989), lies well within this range. These mussel bed areas occurred in spite of fishery, so these estimates can be considered as minimum values of the 'natural' area.

Dankers *et al.* (2003) and van Stralen (2002) described the dynamics of the Dutch intertidal mussel beds. They stated that in most years some spatfall occurs in existing beds. Losses due to storms and ice winters are often compensated by good spatfall outside the remaining beds, but mostly in the neighborhood of or on the remainders of these.

Most intertidal mussel beds in the Dutch Wadden Sea disappeared in the period 1988–1991, after intensive fishery in a period with low spatfall (Dankers *et al.*, 1999). The oldest intertidal beds now present in The Netherlands, with a total surface of about 200 ha (Dankers *et al.*, 2003), are from the 1994 spatfall. The spatfalls of 1999, 2001 and 2003 are the main contributors to the present situation. Based on ground survey and expert judgement the area of intertidal mussel beds in the spring of 2004 was estimated at about 2,200 ha (Steenbergen *et al.*, 2004).

An overview of the development since 1994 of

areas covered with mussel beds in spring and autumn in the Dutch Wadden Sea is given in Figure 8.3.2. These areas are based on ground surveys, as well as a reconstruction of the data in areas that could not be included in the data surveyed completely due to shortage of time, mainly in autumn (Steenbergen *et al.*, 2003a, 2003b). In the reconstruction, data for mussel bed-areas of all years was used in order to compensate for the missing data in the ground surveys. Data of autumn 2003 and spring 2004 can only be reconstructed after the ground survey in spring 2005.

The total biomass of mussels in the intertidal (scattered mussels and mussel beds) is monitored in spring. It has increased from about 11,000 t fresh weight in 1999 to about 74,000 t in 2004 (Steenbergen *et al.*, 2004; Figure 8.3.3).

Since 1991, mussel fishery was restricted to the subtidal part of the Dutch Wadden Sea, with, however, two exceptions. First, some fishery was allowed in the autumn of 1994 on young seed beds of the 1994 spatfall. Most of these seed beds (both fished and unfished) disappeared in early 1995 due to storms. Second, a restricted experimental fishery was carried out in 2001 on beds that were considered unstable, to test the hypothesis that moderate fishery could increase the stability of

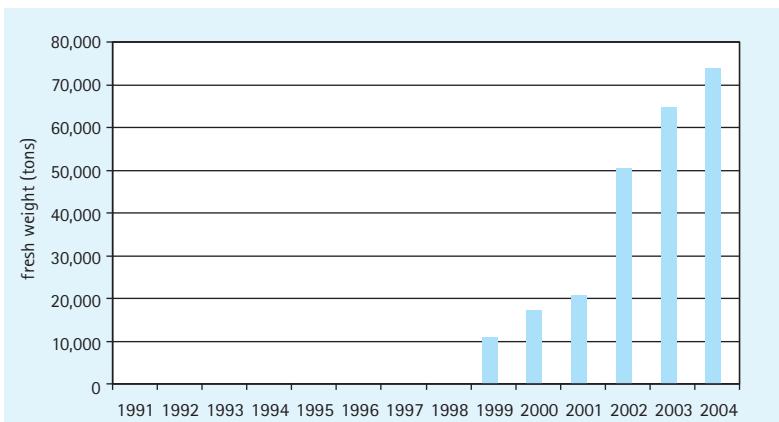
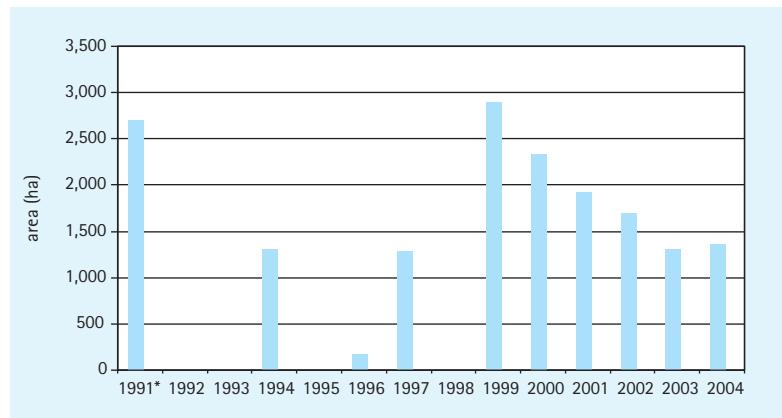


Figure 8.3.3: Total biomass (t fresh weight in spring) of intertidal blue mussels in the Dutch Wadden Sea since 1999 (from: Steenbergen *et al.*, 2004).

Figure 8.3.4:
Development of the total surface area of intertidal blue mussel beds (ha) in Niedersachsen based on yearly spring surveys.
(*1991: refers to the period of 1989–91) (from: Herlyn and Millat, 2004).



young mussel beds. The experimental fishery, however, was unable to prove the hypothesis as autumn and winter storms destroyed the fished as well as unfished mussel beds (Smaal *et al.*, 2003). Therefore, it can be stated that in the Dutch Wadden Sea the mussel fishery since 1991 had no, or at the most a negligible impact on the development of mussel beds on the intertidal flats.

The age structure of the mussels on the mussel beds in the past is not well known, but must have varied considerably (van Stralen, 2002; Steenbergen, 2003b). More than average spatfalls occurred about once per four years, and there are indications of large variations in the size of the beds.

8.3.3.2 Niedersachsen

Mussel beds covered a surface area of up to 5,000 ha during 1950–1987 (Dijkema, 1989; Michaelis *et al.*, 1995). After the mid 1980s, this area decreased to 1,400 ha in 1994, although there was intense spatfall in the summer of 1991. The decrease continued to 170 ha in spring 1996. In 1996, an intense spatfall resulted in the formation of new beds, which survived for some years. Of the young beds from 1996, 1,280 ha endured the ice winter 1996/97.

Some additional spatfalls have occurred since 1996, leading to a mixed population structure. In

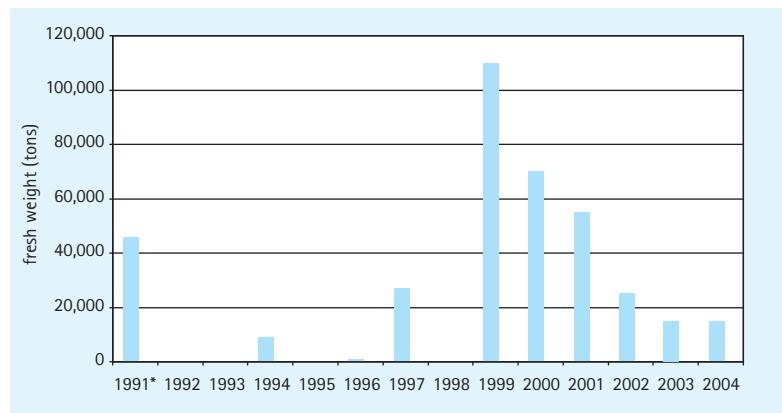
2003 a part of the beds was still dominated by the year class 1996.

In spring 1999, a total area of about 2,900 ha of mussel beds was present. This area diminished gradually during 1999–2003, resulting in a surface reduction of 55%, to reach 1,300 ha in 2003 (Figure 8.3.4). In the area closed for fishery according to National Park Law mussel bed area decreased by 40% from 286 to 172 ha (Herlyn and Millat, 2004). The biomass decreased even more, by about 85%, from about 110,000 t to about 15,000 t (Figure 8.3.5).

8.3.3.3 Schleswig-Holstein

The area of mussel beds present in 1989 was reassessed by analysis of aerial photographs and estimated at 1,500 ha. This is the highest value documented so far in the Wadden Sea of Schleswig-Holstein (Nehls, 2003; Nehls and Ruth, 2004; Stoddard, 2003). Mussel beds at that time originated mainly from the very strong spatfall in 1987, *i.e.* after a series of three cold winters, and covered parts of the higher intertidal flats. The last good spatfall occurred after the severe winter of 1995/96. This 1996 spatfall occurred in locations that were considered to be low in hydrodynamics and mainly settled on the lower parts of intertidal flats; mussel beds were re-established on the high

Figure 8.3.5:
Development of total biomass (t fresh weight) of intertidal blue mussel beds in Niedersachsen based on spring surveys (from: Herlyn and Millat, 2004).



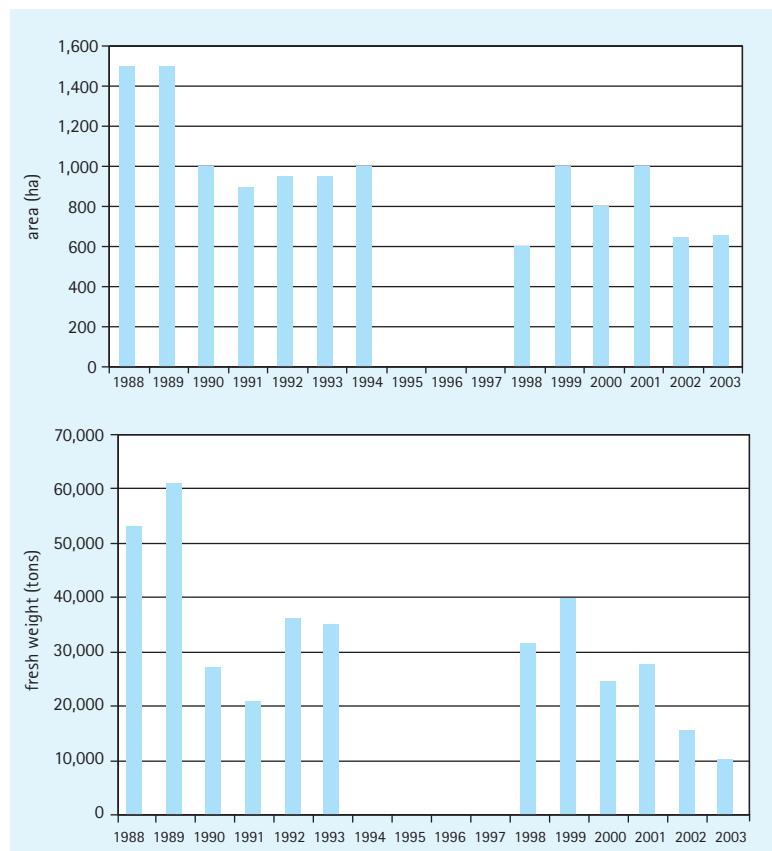


Figure 8.3.6:
Development of total surface area (ha) and mussel biomass (t fresh weight) of intertidal blue mussel beds in the Schleswig-Holstein Wadden Sea based on yearly surveys (spring/summer) (from: Nehls and Ruth, 2004).

flats. Monitoring of blue mussel beds was resumed in 1998 (Nehls, 2003). The surface covered with mussel beds in 1999 was 1,000 ha (Figure 8.3.6). Subsequently, the mussel bed area decreased to 640 ha in 2002. The mussel bed area north of the Eiderstedt peninsula further decreased in 2003 but this loss was compensated by new spatfall in the area south of Eiderstedt. The decrease was mainly the result of storms and lacking recruitment into the mussel beds and was paralleled by a reduction in the coverage within the mussel beds, which decreased from 43% in 1998 to 26% in 2002.

Biomass estimates from before the intensive fisheries of the mid 1980s are not available. After the good spatfall of 1987, 60,000 t (wet weight of the living animal, including shell and enclosed sea water) were present in 1988 and 1989. This decreased to 35,000 t in the early 1990s due to fisheries on 30 of the 64 beds and strong winter gales in early 1990. Since 1992, the majority of the mussel seed fishery occurred in the subtidal and, since 1994, intertidal fishery has been abandoned. Total biomass of intertidal mussel beds reached 40,000 t in 1999 and decreased to 13,000 t in 2003.

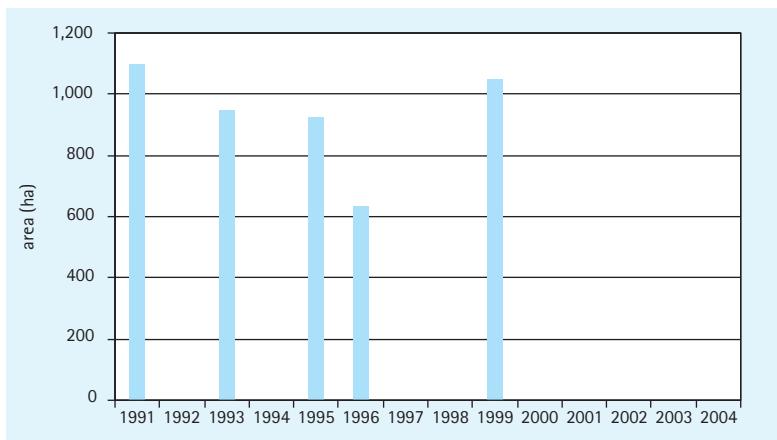
Due to the high dynamics of mussel beds it is difficult to obtain a reference value of what might

be a good ecological state. If the maximum values ever recorded of all individual beds are added up, an area of 2,500 ha would be obtained. This value can be considered as the highest possible mussel bed area which would be present if all intertidal beds reached their highest reported area simultaneously. However, it seems unlikely that this will occur frequently.

8.3.3.4 Denmark

For the Danish Wadden Sea, Munch-Petersen and Kristensen (1987) estimated the total area covered with mussel beds before the overfishing in 1984–1987 at 4,000 ha. This figure was based on aerial photographs and includes scattered mussels ('Streusiedlung') in very large areas. As these areas with scattered mussels do not meet the present criteria for mussel beds, these historic figures should be reduced to about 2,000 ha (Kristensen, personal judgment) to allow a comparison with recent data. After the period of heavy fishery, Munksgaard (1989) estimated the total area of mussel beds to be only about 500 ha in 1989; scattered mussels were not included. In 1991, 1,100 ha were present (Figure 8.3.7) but in 1996 the area decreased again to only 600 ha (Kristensen, 1994, 1995, 1997). In 1999, the area

Figure 8.3.7:
Development of total surface area (ha) of intertidal blue mussel beds in the Danish Wadden Sea based on yearly surveys in spring. A small amount of subtidal beds are included (source: DFU).



had increased again to 1,000 ha (Kristensen and Pihl, 2003). The areas with mussels have varied considerably since the mid 1980s, but never exceeded 2,000 ha. In the Juvre Dyb, Mandø and Knude Dyb areas, the beds have not returned since they were removed by the fisheries. A nature conservation project was started in 2002 to test whether transplantation of seed mussels to Jørgens Lo and Ribe Stream could contribute to the re-establishment of mussel beds in this area. In the Ho Bight area (partly closed for fishery), almost 70% of the original beds returned by an autumn settlement immediately after the breakdown in 1989. This situation remained stable in the years after 1999. Some intertidal beds disappeared and new ones have appeared either in the previous place or in new places. In 2002, 650 – 900 ha of mussel beds were present (Kristensen and Pihl, 2003). So, the area covered with mussel beds as well as their biomass has been very variable over the years (Kristensen, 1994, 1995, 1997; Kristensen and Pihl, 2003).

Most of the intertidal mussel beds in the Danish Wadden Sea are very old (>20 years). Some of the intertidal beds are highly dynamic, while others are not. The oldest and most stable beds are in the southern part of Jordsand, in Ho Bight at Sæd-

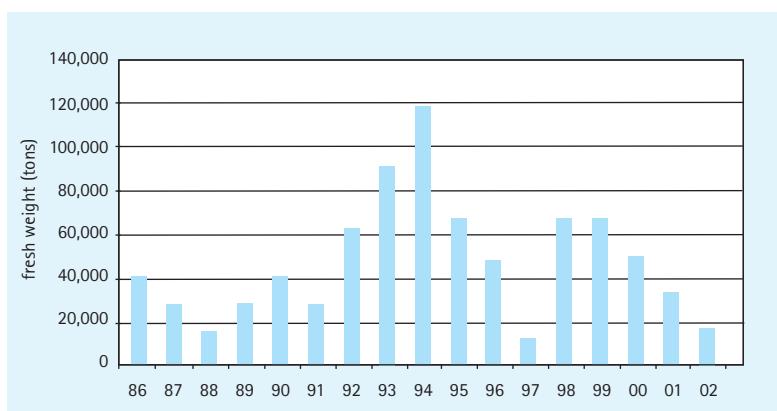
ding Strand and east and west of the isle of Langli. In a few years time they may deteriorate until suddenly a new settlement takes place, such as happened last time in 2003. This means a new era for these mussel beds; the mussels stay there for some years. Due to these dynamics, the biomass of intertidal beds varies considerably over the years. Figure 8.3.8 gives an overview of the biomass of all mussels in the Danish Wadden Sea. This figure includes subtidal mussels, but the contribution of the subtidal mussels is relatively small, both because most beds in the Danish Wadden Sea are intertidal and because the biomass per m² on intertidal beds is higher than on subtidal beds (Kristensen, 2003).

8.3.4 Impact of fisheries/mussel farming on mussel beds

The main reasons why mussel beds disappear under natural conditions are insufficient spatfall, ice covers and storms. These conditions lead to a gradual decrease in mussel bed area as observed in Schleswig-Holstein since 1998 (Nehls, 2003; Nehls and Ruth, 2004). Ice covers were absent from 1997 until 2002, and the storminess did not increase during the last decades (Schmidt, 2001).

As described above, there has been almost no

Figure 8.3.8:
The annual estimated biomass (t fresh weight, in Sept.–Oct.) in the Danish Wadden Sea between 1986 and 2002, including a relatively small amount of subtidal mussels (from: Kristensen and Pihl, 2003).



Absolute (ha) and relative (%) of intertidal area covered by blue mussel beds in the Wadden Sea subareas

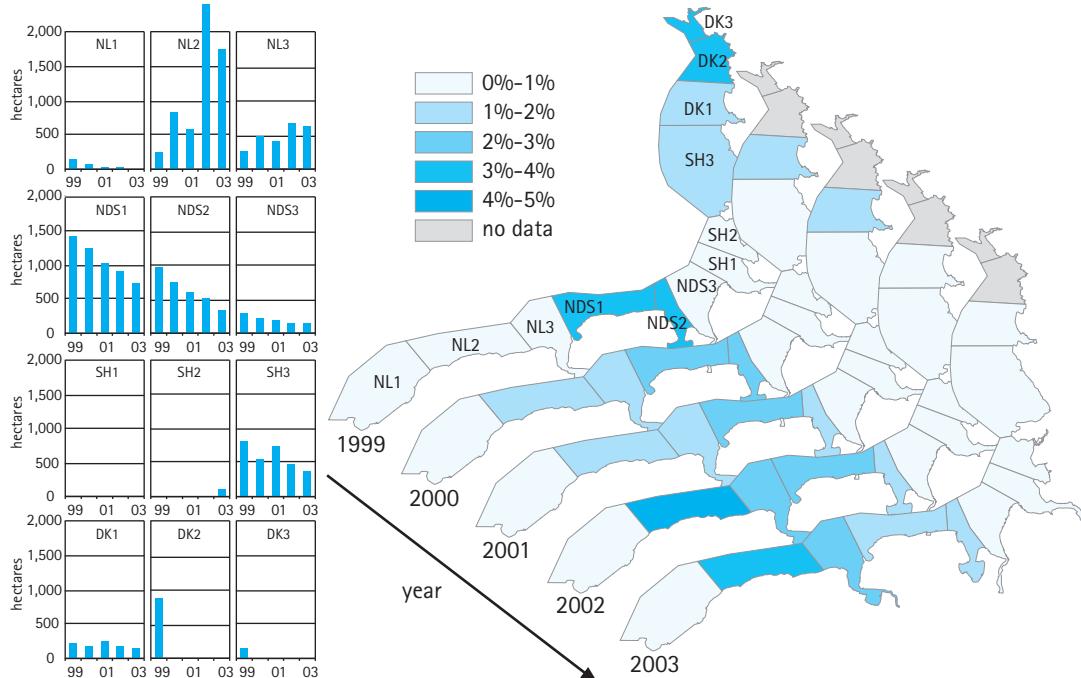


Figure 8.3.9:
Distribution of intertidal blue mussel beds in the Wadden Sea in the period 1999–2003. Shown is the development of the surface area of mussel beds (ha) and the area of intertidal flats covered by mussel beds (%) (calculation based on GIS data, source TMAP data unit).

impact of mussel fishery in the intertidal area of The Netherlands since 1991. Nor has there been any impact of mussel fishery in the intertidal area of Schleswig-Holstein since 1995. In these parts of the Wadden Sea, the seed mussels to stock the culture lots have been obtained from subtidal areas.

In Niedersachsen, the mussel culture still depends on seed mussels from intertidal mussel beds. It is unknown to what extent the harvesting of seed mussels has contributed to the observed losses of hectares and biomass of intertidal mussel beds. In a study on the influence of mussel fishery on stable sites of blue mussel beds in the Niedersachsen Wadden Sea, Herlyn and Millat (2000) showed that in most of the investigated beds mussel fishery led to heavy or even complete losses. These losses were larger than the amounts of mussels actually removed by fishery.

By the end of 2004, a new management plan for mussel fishery in Niedersachsen was adopted which allows continuation of the seed mussel fishery in the intertidal area.

In Denmark, the intertidal beds remained unfished since 1992.

In conclusion, it can be stated that in The Netherlands, in Schleswig-Holstein and in Denmark the direct impact of mussel fishery on the natural development of intertidal mussel beds has been limited or absent during the last years. Fishery went on in Niedersachsen. Further research on long-

lasting effects of mussel fishery on the fate of fished beds and on the effects on mussel stocks of larger areas, e.g. tidal basins, is necessary.

The recovery of mussel beds as observed in The Netherlands is mainly attributed to the prohibition of the mussel seed fishery on the intertidal flats (Ens *et al.*, 2005). Observations in Schleswig-Holstein and Denmark show that in the long run existing mussel beds will deteriorate when no recruitment occurs, and the total surface of beds will diminish due to storms and ice cover as long as these losses are not compensated by new settlement of mussel spat.

Aerial photograph of a fished blue mussel bed ('Jan-Louw'-bank), Texel, (Photo: K. Kersting)



8.3.5 Bio-invaders

Mussel beds represent a hard substrate favorable for settlement of sessile epibionts. The most important invaders are the gastropod *Crepidula fornicata*, the Pacific oyster *Crassostrea gigas* and the Australian barnacle *Elminius modestus*.

Crepidula is increasingly abundant on subtidal culture lots in the Dutch Wadden Sea. Currently, high population densities are present on mussel beds of the Jade-Weser-Elbe estuary and in the northern Wadden Sea (Thielges *et al.*, 2003, Wehrmann and Schmidt, unpubl.). Being a filter-feeder, *Crepidula* competes for food with the mussels when occurring in high abundances, causing significant reduction in growth of blue mussels (Thielges, 2005).

The most obvious change in the community structure of mussel beds is being caused by the Pacific oyster. This species competes with the native blue mussel for food as well as for space. Due to its high growth rate and successful recruitment, the Pacific oyster is considered a potential risk to the mussel beds of the Wadden Sea. On the other hand mussels and oysters can form complex and biodiverse communities with algae, periwinkles and abundant mussel spatfall (see also chapter 6 'Introduced Species').

Elminius modestus was introduced from Australia. It strongly outcompetes other barnacle species (Nehring and Leuchs, 1999). Although barnacles have negative effects on mussel growth (Buschbaum and Saier, 2001), they also have a positive effect by increasing mussel recruitment (Saier, 2001; Buschbaum, 2002).

Pacific oyster in a blue mussel bed
(Photo: G. Millat).



8.3.6 Conclusions

Spatfall is a crucial process in the population dynamics of blue mussels. The determining factors for spatfall are still not well understood, nor is the cause of regional differences in spatfall within the Wadden Sea.

In The Netherlands, measures to increase the area of naturally developing mussel beds have been successful, but this lasted more than 10 years until a surface of about 2,000 ha of more or less stable beds (most of these having survived two winters) was reached. Most of these beds are situated in the eastern part of the Dutch Wadden Sea, where good recruitment occurred in 1994, 1999, 2001 and 2003. Very few beds, however, have developed in the western half of the Dutch Wadden Sea. In Niedersachsen, Schleswig-Holstein and Denmark, there was a rather good spatfall in 1996, leading to establishment of beds that still survive. However, lack of recruitment since 1999 has caused deterioration and overall loss of biomass.

Besides recruitment success, the impact of storms and ice cover is of major importance for the long-term development of mussel beds, especially in the Schleswig-Holstein and Danish part of the Wadden Sea.

In The Netherlands and in Schleswig-Holstein the direct impact of mussel fishery on the natural development of mussel beds has been limited or absent during the last years. In Denmark, the impact was restricted to subtidal areas in Ho Bight and in the northern part of the Lister Deep. In Niedersachsen, mussel fishery may have contributed to additional reduction of mussel bed area and biomass.

Progress was made regarding the protection of young mussel beds on old sites of mussel beds, which are considered to provide the best chances for settlement of new beds. In The Netherlands, fishery of seed mussels will be allowed in 'unstable' locations only, and in Schleswig Holstein no fishery is allowed at all in the intertidal. In the Danish Wadden Sea, part of the intertidal beds are still open to fishery, irrespective of their potential to develop stable mussel beds. In Niedersachsen, the management plan was amended in 2004 and allows for seed mussel fishery in the intertidal.

As a follow-up of the 1999 QSR, a protocol was developed for harmonized description and area measurement of intertidal blue mussel beds, providing a useful tool for further assessments.

8.3.7 Target evaluation

The targets of the Wadden Sea Plan are (1) an increased area and (2) a more natural distribution and development of natural mussel beds. This target was set after a period of overfishing of many intertidal beds and relatively low stocks. Since then, strict regulations have been applied in most of the areas.

The increased area was reached in the middle and the eastern part of the Dutch Wadden Sea, but not in the western part. In Niedersachsen, the current total area of mussel beds is still below the level present in the late 1980s despite the recovery after the spatfall of 1996. In Schleswig-Holstein, the area of mussel beds is still below the level present in the early 1990s. In the Danish Wadden Sea no development according to the target occurred.

The more natural distribution and development of intertidal mussel beds, as far as possible with competition by bio-invaders and changes in climate, may have been achieved in all areas where there was no fishing on intertidal mussel beds. This applies to most of the beds in The Netherlands, 25–30% of the mussel bed sites in Niedersachsen, all beds in Schleswig Holstein and all beds in Denmark.

8.3.8 Recommendations

Research is needed to provide insight into the spatfall process in general, and the cause of low recruitment of intertidal mussels and mussel beds.

The biotope 'intertidal blue mussel bed at stable sites' should be considered within the Water Framework Directive as a biological quality element for coastal waters.

The settlement of Pacific oysters may have a major impact on the mussel beds and their biomass in the near future. Therefore, the proliferation of the Pacific oyster in and outside mussel beds should be monitored together with associated changes in the structure of the mussel beds. A common approach should be developed also aiming at the development of management tools that could be used to reduce the influence of Pacific oysters on mussel beds.

To extend – if possible – the habitat model for intertidal mussel beds developed as a management tool for the Dutch Wadden Sea to the German and Danish Wadden Sea too.

The management measure of protecting stable mussel beds or sites is still valid.

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8.4 Seagrass



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Eelgrass *Zostera marina*
(Photo: H. Marencic)

8.4.1 Introduction

Seagrasses occur in shallow waters of almost all coasts. In the Wadden Sea these submerged flowering plants are represented by two species of the genus *Zostera*. The small and very narrow-leaved *Z. noltii* is the most common. It grows in the intertidal zone and is usually perennial although leaves are scarcely seen in winter. It is often accompanied by a mostly annual, narrow-leaved flexible, small morph of the large *Z. marina*, growing particularly in puddles which remain filled with water at low tide. Around the low-water line and deeper, beds of a large and perennial *Z. marina*, with rigid bases and broad leaves, once occurred in the western and northern Wadden Sea. In the course of a wasting-phenomenon in the early 1930s these beds vanished and never came back. The primary cause of the decline of the perennial *Z. marina* beds might have been anomalously cloudy and/or warm years in the 1930s, and the conspicuous infestation with the pathogenic protist *Labyrinthula zosterae* – a response to the already weakened eelgrass (den Hartog and Phillips, 2001). In spite of this historic decline, a high allelic diversity was observed in the Wadden Sea, indicating a confluence of populations in this region (Olsen *et al.*, 2004). *Z. noltii* also shows a high diversity (Coyer *et al.*, 2004).

Zostera beds, with their dense growth, protect the sediment against erosion and facilitate deposition. They provide a substrate for fouling algae which in turn are grazed by snails and other invertebrates. The canopy and rhizomes offer protection for small animals such as juvenile bivalves, crustaceans and fishes which utilize the beds as a

nursery. *Zostera* beds constitute a food for brent geese and wigeon. In the Wadden Sea at present, most beds are to be found in the mid to upper tidal zone along the leeside of islands and high sand bars as well as along sheltered parts of the mainland coast. A conspicuous decline of the intertidal beds of *Z. noltii* and *Z. marina* has occurred since the 1950s or 1960s, suspected to have been caused by human impacts as outlined in the 1999 QSR. This situation led to the target of 'an increased area and a more natural distribution and development of *Zostera* fields' agreed upon in the Trilateral Wadden Sea Plan (1997). This requires an evaluation of the current status of the seagrass populations and an explanation for the development, in order to propose sensible recommendations.

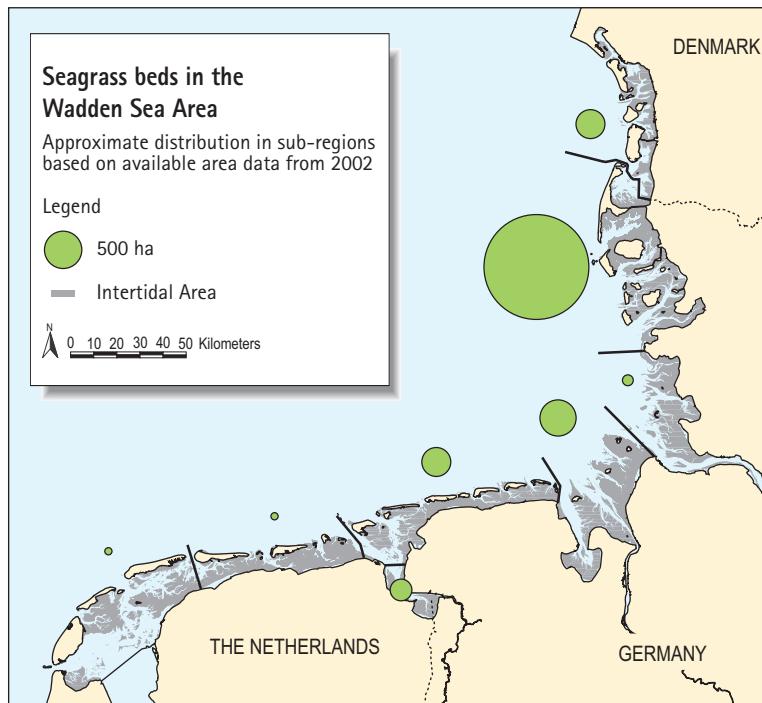
Target

An increased area of, and a more natural distribution and development of natural mussel beds, *Sabellaria* reefs and *Zostera* fields.

8.4.2 Distribution of seagrass beds in the Wadden Sea

The occurrence of seagrass beds in the Wadden Sea is rather uneven. From a rough aerial survey in 1998 with a total of 5,100 ha of seagrass beds recognizable from a plane, it is estimated that more than 90% of the beds occur in the northern Wadden Sea between the Eiderstedt and Skallingen peninsula (Reise, 2001). In 2002/03 the total seagrass cover for all sub-regions was about

Figure 8.4.1:
Distribution of intertidal
seagrass beds in the
Wadden Sea (in ha) in
different sub-regions in
2002.



7,300 ha with 82% in the northern part (combination of aerial and ground surveys). Most seagrass beds occur on the leeside of islands and in the shelter of high sand bars. Only a few beds are present in the central estuarine part between the Eider, Elbe and Weser, while larger beds are found in the Jadebusen embayment and the Ems estuary. The occurrence along the East Frisian and West Frisian mainland is rather sparse and beds on the leeside of these barrier islands remain small (Figure 8.4.1).

8.4.2.1 Southern and central Wadden Sea

The region from Den Helder to the Elbe estuary has been subject to a continuous decline in number and size of seagrass beds in the tidal zone since about the 1960s (Den Hartog and Polderman 1975, de Jonge *et al.*, 1993, Michaelis *et al.*, 1971, Kastler and Michaelis, 1999). In the Dutch part of the Wadden Sea, *Z. marina* was in 2000–2003 confined to a few small patches at Terschelling, Schiermonnikoog, Rottumerplaat, the Groningen coast

and the Ems estuary. Most of the small occurrences were ephemeral and a previously permanent bed vanished from Terschelling harbour. On the other hand, on the tidal flat Hond-Paap in the Ems estuary a large bed of 100 ha has developed from patches of only 2 ha in the course of the last 10 years. Seeds originating from this bed probably drifted to the bordering Groningen coast where since 2003 a seagrass location of 10 ha with a coverage of 5–10% has been found. Elsewhere *Z. noltii* is more common than *Z. marina* and was observed in 2000–2003 at Terschelling, Ameland, Rottumerplaat and along the Groningen coast with a total area of about 100 ha (Figure 8.4.2).

In the Niedersachsen part of the Wadden Sea, more seagrass is present than in the Dutch part. It was estimated that seagrass occurred on 750 ha in 2002 (Adolph *et al.*, 2003). Nine years earlier the estimate was 700 ha. *Z. marina* is generally sparse, not forming dense beds anywhere, and has further decreased since the last survey in 1993–94. A recent areal increase in beds of *Z. noltii* was

Table 8.4.1:
Long-term occurrence of
Zostera in the Jadebusen
with areal coverage,
dominant species and
locations with largest beds
(from data in Kastler and
Michaelis, 1997 and Adolph
et al., 2003)

Period	ha	<i>Zostera</i> sp.	Main locations
1935–1937	530	<i>noltii</i>	Bockhorner-Sander, Vareler, Seefelder and Stollhammer Watt
1975–1977	280	<i>marina+noltii</i>	Vareler Watt
1993	350	<i>noltii+marina</i>	Seefelder Watt
2000–2002	580	<i>noltii</i>	Seefelder Watt, Schweiburger Watt, Arngast Sand

noted along the mainland shore at Norddeich and Neßmersiel, at Itzendorfplate south of Juist, near Wangerooge and particularly in the Jadebusen. In this embayment the largest beds, with together almost 600 ha were recorded. Although seagrass has been continuously present with both species in Jadebusen since at least the 1930s, conspicuous changes in sizes and positions of beds and species dominance occurred in the long term (Table 8.4.1). An almost coherent belt along the shore of *Z. noltii* in the 1930s became confined to a large *Z. marina* dominated bed in the southwest in the 1970s. This had almost vanished in the 1990s, while a large mixed bed showed up in the east. This bed was still there in 2000/2002 but completely dominated by *Z. noltii*. In the Weser estuary some beds of *Z. noltii* vanished between 1993 and 2002. Only one bed of seagrass was observed in 2002 along the mainland shore between the Weser and Elbe.

In the tidal area between the Elbe and Eider estuary, only *Z. noltii* is present. A recurrent bed is found on the leeside of a high sand bar (Blauort) and a few small beds occur inside brushwood groynes along the southern shore of the Eiderstedt peninsula and Tümlauer Bucht. All together, this is an area of about 100 ha of seagrass beds in 2003.

8.4.2.2 Northern Wadden Sea

In contrast to the southern and central Wadden Sea, no general decline in seagrass beds has been observed in the region between the Eiderstedt and Skallingen peninsulas. The recent development between Eiderstedt and the Danish/German border shows an increasing trend since 1994 but this is within the range of the situations in 1978 and 1991 (Figure 8.4.3). The peak extension with almost 7,000 ha in 1991 was the culmination of a notable spread of *Z. marina* throughout the 1980s, followed by a return to smaller beds and strong dominance of *Z. noltii* as observed also in the 1970s. The mean total areal coverage of seagrass beds in the North Frisian Wadden Sea over the last 10 years was 3,800 ha with a range from 2,500 to 5,900 ha. This figure does not include scattered growth and is sometimes blurred by green algal mats blending into seagrass beds. The largest seagrass beds in this region are found east and north of Pellworm, at Südfall, Gröde, Hooge, Langeness, Oland and Sylt (Figure 8.4.4).

Often, seagrasses are rooted in clayey soil of flooded medieval marshes. This is also the case in the West Frisian Wadden Sea near Terschelling. Ground surveys at a few sites since 2000 have generally confirmed the dominance of *Z. noltii*.

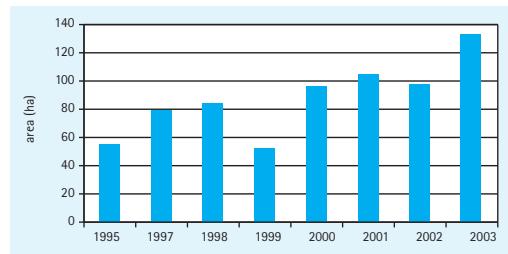


Figure 8.4.2:
Tidal flat area with seagrass
(ha) in the Dutch Wadden
Sea compiled from direct
observation at ground level
between 1995 and 2003
(Dutch monitoring
program, MWTL; see also
www.zeebras.nl).

Well mixed beds of both species were rather scarce, and only a few pure *Z. marina* beds were found, usually as patches in the lower tidal zone.

Genetic analyses of *Z. marina* throughout the North Frisian population indicate relatively high heterozygosity and strong gene flow over a distance of 60 km, probably by rafting reproductive shoots (Reusch, 2002). Similar results were obtained for *Z. noltii* around the island of Sylt and grazing waterfowl were suggested as a likely vector for seeds (Coyer *et al.*, 2004).

The development of seagrass in the Danish Wadden Sea seems to be similar to the adjacent North Frisian tidal area. Large beds currently occur at the leeside of Rømø and Fanø as well as between Jordsands Flak and Koldby. Both *Zostera* species are present. An aerial survey in the northern Lister Dyb and in the Juvre Dyb tidal area revealed 430 ha of seagrass beds (Amternes Vadehavssam arbejde, 2004).

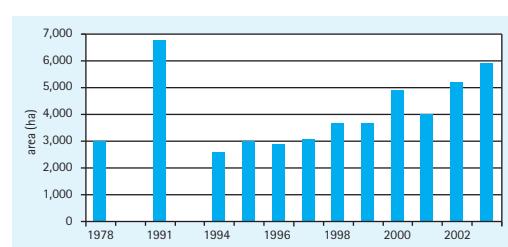
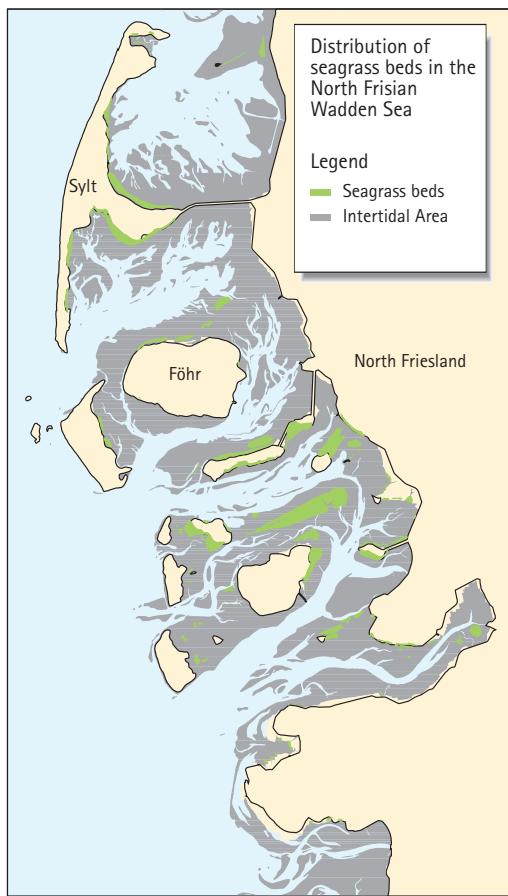


Figure 8.4.3:
Tidal flat area with seagrass
beds (ha) in the North
Frisian Wadden Sea
between Eiderstedt and
Sylt, compiled from aerial
surveys conducted in
August or September
between 1978 and 2003.

8.4.3 Natural fluctuations

Regular annual surveys in the Wadden Sea, which started at some localities in the 1990s, reveal considerable expansions and contractions from one year to another in the size of seagrass beds and in lateral shifts in the position of individual beds (see <http://www.zeebras.nl/>). These fluctuations are probably related to variations in seed dispersal and seedling survival on the one hand, and differential mortality outside the growing season. In general, the mainly annual *Z. marina* populations in the Wadden Sea have a higher variability in abundance and positions than *Z. noltii*, which tends to sprout from bi- or perennial rhizomes although germination from seeds occurs as well.

Figure 8.4.4:
Distribution of intertidal seagrass in the North Frisian Wadden Sea in 2002 (NPA Tönning).



Fluctuations are also evident in the long term. Repeated surveys in Jadebusen show variations in the total extent of seagrass beds from 280 to 580 ha, with a waxing and waning of individual beds within the embayment of still higher variability and including shifts in the relative share of the two species of *Zostera* (Table 8.4.1). Similar changes occurred in Königshafen near Sylt (Reise *et al.*, 1989, unpubl. records). In the 1920s an intertidal coherent belt with *Z. noltii* above, small morphs of *Z. marina* below and a large morph of *Z. marina* at permanently submerged sites was recorded. The latter vanished in the 1930s and the belt disintegrated into five separate beds, which were still there in the 1970s but rather small at that time, and three were completely dominated by *Z. noltii*. In the 1980s *Z. marina* achieved dominance at all sites and beds became larger. In the 1990s bed size and density declined and *Z. noltii* regained its former dominance.

Our understanding of such long-term changes is still rather rudimentary due to the many physical and biotic covariates involved. The degree of synchrony in changes between localities is low. Therefore, direct effects of regional climatic or hydrographic trends or events may not explain

these changes. Instead, combinations of local and stochastic physical events (e.g., sedimentation, erosion, ice scoring, storms) and biotic interactions (e.g., bioturbation by lugworms or preying on seedlings by ragworms; see Philippart, 1994; Hughes *et al.*, 2000) are more likely to be responsible. Grazing by waterfowl such as brent geese and widgeon, which is accompanied by digging up rhizomes, may amount to a loss in phytomass by two-thirds from September to December (Nacken and Reise, 2000). However, when the plots of netted bird exclosures were revisited next summer, leaf density was lower compared to the ambient seagrass bed. This surprising result may be explained by self-inhibition or by herbivore stimulation.

8.4.4 Threats to seagrasses

Centuries of successive embankments converted brackish water environments, upper tidal zones and embayments of the Wadden Sea region into land or enclosed lakes (Reise, 2005), destroying seagrass habitats along the mainland shore. In the zone in front of embankments or dams, many former freshwater runnels have been blocked or confined to a few pumping stations. The germination success and vitality of seagrass tends to be higher under less saline conditions. The lack of recovery in former beds of perennial, permanently submerged *Z. marina* after the wasting phenomenon in the 1930s at Sylt and in the mouth of the Zuiderzee embayment may be linked to the completion of the Hindenburgdamm in 1927 and of the Afsluitdijk in 1932.

More generally, progressive embankment of upper tidal zones in combination with ongoing sea level rise resulted in enhanced hydrodynamics in front of the dikes which in turn caused fine-particulate mud flats to turn into more coarse-particulate sand flats (Flemming, 2002; Dellwig *et al.*, 2000; Mai and Bartholomä, 2000). This habitat change in the nearshore zone is likely to affect the development of seagrass beds occurring there. Moreover, land reclamation works may affect seagrass beds where regular digging of parallel ditches for drainage and sedimentation is involved. Brushwood groynes alone may not have negative effects as beds of *Z. noltii* are often observed within the enclosed rectangular fields. Occasionally, however, groynes trap drifting green algae, suffocating the seagrass growing between the groynes (Reise 2003: Figure 3.2.3-4).

Cockle fishery as practiced in the Dutch Wadden Sea until 2004 destroys existing seagrass beds if license rules to stay outside known seagrass stands are disregarded and may prevent recolonization.

zation. At the coast of Groningen, seagrass beds occurred inside and outside brushwood groynes when cockle fishery was not carried out in 1999 but were confined to within the protective brushwood groynes when cockle fishery approached the groynes in 2001 and 2002 (Essink *et al.*, 2003).

Any explanation for the general decline of intertidal seagrass beds in the southern and central Wadden Sea from about the 1950s to 1990s needs to account for the absence of such a decline in the northern Wadden Sea. Therefore, a general reference to turbidity, salinity, herbicides, shellfish fishery or eutrophication may not qualify as a sufficient explanation because these factors either comprise the entire Wadden Sea or only part of the region where the decline occurred.

For *Z. marina*, experiments suggest that (1) when nitrogen loading is high, eelgrass performs better at estuarine sites with low salinity as observed in the Ems estuary compared to conditions elsewhere in the Dutch Wadden Sea, and (2) wave action prevents eelgrass from growing in the lower tidal zone except at very sheltered locations, *i.e.*, behind a mussel bed or in embayments (van Katwijk *et al.*, 1999, 2000, van Katwijk and Herms, 2000). Susceptibility to hydrodynamics also applies to *Z. noltii*. Experimentally accelerated and decelerated tidal flow over a seagrass bed, as well as transplants between exposed and sheltered beds, showed that higher hydrodynamics (1) directly affect shoot density and plant architecture, and (2) indirectly affect the density of the mud snail *Hydrobia ulvae*, which at high density prevents harmful epiphyte growth on the seagrass leaves (Schanz and Asmus 2003; Schanz *et al.*, 2002).

These experiments performed on *Z. marina* and *Z. noltii* together point to a significant role of hydrodynamics on the distribution of seagrass in the Wadden Sea, in conjunction with eutrophication in the form of toxic effects of high ammonium or nitrate concentrations and indirectly by enhancing epiphyte growth on the leaves. This combination of hydrodynamics and eutrophication could possibly explain why a decline of seagrass beds occurred in the southern and central Wadden Sea but not in the northern part. In the northern Wadden Sea levels of nutrient concentrations tend to be lower (van Beusekom *et al.*, 2001. see chapter 5 'Eutrophication'), and due to the orientation of the coast perpendicular to the prevailing westerly storms, the islands and sand bars offer an effective shelter against wave action. Diminished freshwater runoffs because of impermeable dikes may also attain an important role in nearshore areas.



Transplantation of seagrass in the Dutch Wadden Sea (Photo: H. Wolter).

An increasing frequency of strong westerly winds over recent decades is hitting a coast where the position of the dike-line and the sea level are far from in equilibrium, and thus it is highly susceptible to wave disturbance. In this situation, seagrass beds become squeezed and with global warming and accelerated sea level rise conditions may become worse in the long run. Restoring continuous freshwater runoffs along the coast, a decrease in eutrophication, recovery of intertidal mussel beds and a ban on cockle fishery in the tidal zone, on the other hand, may help to mitigate the sad fate of the seagrass. Another potential threat to seagrass may be an increased requirement for dredging in Rotterdam harbors as a consequence of an increasing Rhine discharge. This may well enhance turbidity in the western Wadden Sea to levels detrimental for seagrass (de Jonge and de Jong, 2002).

8.4.5 Reintroduction of eelgrass

Assuming that *Z. marina* is unable to recolonize potentially suitable habitats because the few remnant beds left in the southern Wadden Sea do not provide sufficient propagules, recovery may benefit from reintroductions. Van Katwijk (2003) reviewed such attempts made in the Dutch Wadden Sea during the 1990s and concludes that transplants should focus on (1) the tidal zone between +0.1 and -0.2 m mean sea level, (2) muddy sediment in depressions to allow for a permanent layer of water throughout low tide periods (van Katwijk and Wijgergangs, 2004), (3) locations where mussel beds provide shelter against wave action, and (4) locations with freshwater seepage or runoff locally reducing salinity. This seems to characterize the optimal niche under present conditions in the Wadden Sea. Currently, the reintroductions have led to a number of *Z. noltii* patches since 1993 and to a *Z. marina* bed varying from 25 up to 800 plants within an area of 3–5 ha since 1999. The latter variation in plant density seems

to be related to macroalgal abundance. A new reintroduction and monitoring program is being carried out in the period 2002–2005, testing density, planting unit size, mussel bed presence, and investigating seed production. The possibility to re-introduce the robust morph of *Z. marina* which vanished from the lower intertidal to upper subtidal zone in the wasting phenomenon of the 1930s has not yet been explored.

8.4.6 Conclusions

A decline of intertidal seagrasses in the southern and central Wadden Sea from the 1950s to the 1990s seems to have come to an end, and some slow recovery is evident. Both species, *Z. marina* and *Z. noltii*, show considerable fluctuations between years in the size and shape of local beds. This is also the case in the northern Wadden Sea where no decline was noted and at present more than 80% of seagrass area occurs. Experiments revealed that at average salinity, nutrient loads had negative effects on *Z. marina*, while at estuarine salinities the same nutrient loads had positive effects. Outside embayments, seagrass distribution is confined to the upper tidal zone where duration of wave exposure is shorter per tidal cycle than in lower zones. Eutrophication and hydrodynamics seem to be the overall variables determining seagrass distribution in the Wadden Sea, while positive effects of low salinity and negative effects of shellfish fishery and land reclamation works are of an important but more local relevance. In the coming decades, hydrodynamics are expected to constitute an increasing stress to seagrass beds in the Wadden Sea which hopefully will be mitigated to some extent by decreasing effects of eutrophication and prohibition of shellfish exploitation in the intertidal zone.

Seagrasses are in world-wide decline (Green and Short, 2003). They are indicative for a broad range of environmental impacts, provide habitats for diverse species assemblages and mitigate coastal erosion. In the Wadden Sea, monitoring of seagrass is still performed at diverging levels of accuracy in the different sub-regions, mainly due to widely differing sizes of vegetated areas and differing efforts. As a consequence, it is still unknown how much *Z. marina* and *Z. noltii* occurs in the entire Wadden Sea, and general trends in de-

velopment can not easily be separated from more local phenomena and fluctuations.

We suggest conducting a complete and concerted ground survey throughout the Wadden Sea about every 10 years. In addition, 30 to 50 sites should be selected for detailed analyses of population developments. This number is assumed to be necessary to take into account the diverse habitat types under which *Z. noltii* and *Z. marina* are growing or may potentially grow. Potential sites for which actual records of seagrass are lacking should be included. On the other hand, monitoring at fewer sites at a high temporal resolution is to be preferred over monitoring every 2–3 years at more sites. A basis is needed to quickly detect changes in seagrass development during vegetation periods. Measurements of a wide spectrum of growth characteristics have the potential to provide a clue to possible causes of change.

8.4.7 Target evaluation

The Target of an increased area of *Zoster* fields has not yet been met in all sub-regions of the Wadden Sea.

8.4.8 Recommendations

- Given the diminished and still endangered state of seagrasses in the southern and central Wadden Sea, disturbing effects of shellfish fishery and land reclamation works at existing and potential sites of seagrass beds should be avoided.
- Further reductions in nutrient loads would strengthen the vitality of seagrass when growing at average salinities.
- Restoring of ebb-sluisches with continuous freshwater runoffs to explore their beneficial effects on local seagrass development.
- Reintroductions of intertidal seagrass in the southern Wadden Sea should focus on optimal sites and employ founding populations of considerable size to achieve self-maintenance.
- Attempts should be made for experimental reintroductions of the large morph of *Z. marina* at former sites in the western and northern Wadden Sea.
- A trilateral working group needs to be established to considerably improve seagrass monitoring and research in the Wadden Sea.

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8.5 Subtidal Habitat Structures



Sabellaria reef-lump dredged in the Jade near Hooksiel in 1991
(Photo: R. Vorberg).

Ralf Vorberg

8.5.1. *Sabellaria* reefs

8.5.1.1 Introduction

Biogenic structures as present at the intertidal flats of the Wadden Sea in the form of seagrass beds, blue mussel beds and more recently of Japanese oysters, also occur in the subtidal. Polychaetes of the species *Sabellaria spinulosa* produce reef-like structures in the subtidal of the Wadden Sea. Here, the information presented in the 1999 QSR (de Jong *et al.*, 1999) is updated.

Polychaetes of the family Sabellariidae occur worldwide along the shores of temperate seas. *Sabellaria spinulosa* is a common and widespread polychaete species in the North Sea. Their larvae can be observed regularly in zooplankton catches during summer. Single worm-tubes are frequently found in the entire Wadden Sea area on pebbles, mussel shells and other hard substrate. Only under certain circumstances colonies are built, forming massive, reef-like structures. Reefs of *Sabellaria spinulosa* have been known to occur in the subtidal of the German Wadden Sea for more than 100 years (Meyn, 1859; Möbius, 1893). Records of such reefs from the Dutch and Danish Wadden Sea, however, do not exist. In the 1999 QSR, *Sabellaria* reefs were reported to be present at only three locations in the German Wadden Sea.

8.5.1.2 Status of *Sabellaria* reefs

Sabellaria reefs are not known in the Danish nor Dutch Wadden Sea and adjacent coastal waters. In Dutch coastal waters, however, the species *Sabellaria spinulosa* was recorded on artificial reefs in 1992 (van Moorsel, 1993).

For the German Wadden Sea, Vorberg (1995) has compiled a list of 24 reefs occurring there during the last 100 years (Fig. 8.5.1). In the early 1990s most of these places were revisited, but only three living reefs could be found. In the Jade near Hooksiel (Fig. 8.5.1.1), reef structures were detected in 1991 by means of dredge sampling. Sonar surveys in 1995 indicated that the reef covered an area of about 140 hectares. Close to this location on the other side of the Jade shipping channel a second reef has existed for many decades, as proven by regular dredge sampling since 1977 at this location by the Senckenberg Institute, Wilhelmshaven. The condition of this reef changed over the years from bad and uninhabited (*i.e.* without living worms) to good and densely inhabited. Information, however, concerning the actual status and quality of this reef does not exist.

A methodological study was performed in 1997 to survey the *Sabellaria* reef in the Jade near Hooksiel by means of echo sounding (Rahmel *et al.*, 1999). The seabed classification system used in this study did not succeed in proving the existence of reef structures. More accurate observations by divers, however, revealed the existence of some *Sabellaria* clumps covering an area of about 1 m². These reef fragments were uninhab-

Target

A increased area of, and a more natural distribution and development of natural mussel beds, *Sabellaria* reefs and *Zostera* fields.

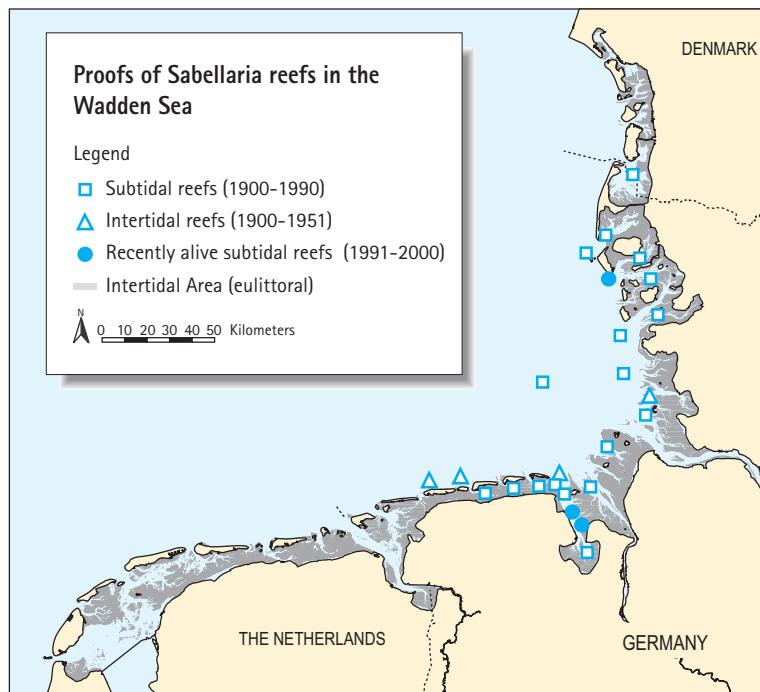


Figure 8.5.1:
*Proofs of *Sabellaria* reefs in the Wadden Sea*

ited. Compared with earlier observations at the same site (Vorberg, 1997) the reef extension had obviously diminished drastically and the remainder seemed to be in a poor condition. But a few years later, in autumn 2000, grab and dredge sampling by Grotjahn (2000) revealed larval settlement on the remainder of the reef. The reef lumps found in the dredge samples were occupied by many tiny tubes with living worms inside. Larval settlement on old worm tubes is a well-known phenomenon for this polychaete species (Pawlak, 1992). The larvae are capable of detecting reef structures biochemically regardless as to whether the reef is living or dead.

The third reef was found in 1993 south of Amrum in the Rütergat (Fig. 8.5.1). Underwater video records showed reef structures covering an area of about 18 hectares. In 2002, a survey using a multi-beam echo sounding system could not detect reef structures at the 1993 reef location (Heineke *et al.*, 2002). It remains unclear whether the *Sabellaria* reef disappeared completely, shifted, or was covered up by a sediment layer.

8.5.1.3 Target evaluation

In the Trilateral Wadden Sea Plan (1997), a specific Target for *Sabellaria* reefs was adopted aiming at an increased area, a more natural distribution and development of *Sabellaria* reefs.

With respect to *Sabellaria* reefs, there has been

a dramatic development. Bottom trawling and aggregate extraction are considered to be damaging to *Sabellaria* reefs and could have promoted their decline (Riesen and Reise, 1982; Holt *et al.*, 1997). On the other hand, the findings of Vorberg (2000) indicate that the occurrence and distribution of *Sabellaria* reefs are not affected by shrimp fishery, but more dependent on changes in water current conditions.

Due to their dramatic decline during the last decades, *Sabellaria* reefs were placed on the Red List of Biotopes and classified as threatened with complete destruction (Ssymanek and Dankers, 1996). The importance of *Sabellaria* reefs to marine biodiversity is well known and the intention for their protection exists on different levels.

Conservation of reefs is required in the Habitats Directive (Annex I) and *Sabellaria* reefs can also be protected as a Special Area of Conservation (SAC) within the NATURA 2000 network.

In contrast to this apparent need for conservation, no specific measures to protect the last few *Sabellaria* reefs were implemented. Neither was a program launched to specifically monitor the known reefs and explore the possible existence of reefs elsewhere. There is a serious lack of knowledge regarding the present occurrence of *Sabellaria* reefs in the Wadden Sea Area, and of the primary conditions for the genesis and further development of these reefs.

8.5.1.4 Recommendations

The last known *Sabellaria* reefs in the Wadden Sea Area should be properly protected, especially from damage due to seabed disturbing activities such as sand extraction, dredging and bottom trawling with heavy fishing gear.

Anthropogenic measures which have the effect of changing water current conditions (e. g. building of dykes, jetties and groynes) should be

planned carefully if a *Sabellaria* reef could potentially be affected.

A program should be launched under the TMAP to properly monitor existing *Sabellaria* reefs, and to explore the occurrence of reef structures elsewhere. For these undertakings the methods that were recently tested in the German Wadden Sea by Heineke *et al.* (2002, 2003) could be used.

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8.5.2 Subtidal blue mussel beds

8.5.2.1 Introduction

In the 1999 QSR it was concluded that there was hardly any information on the development of older stable mussel beds in the subtidal of the Wadden Sea. In this section information will be presented on the occurrence and development of mussel beds in the subtidal as well as on subtidal culture lots used by mussel farmers. The main known subtidal mussel beds are in the western Dutch Wadden Sea, in the Schleswig-Holstein area and Ho Bugt in Denmark.

8.5.2.2 Ecosystem of subtidal mussel populations

Subtidal mussel beds mainly occur in shallow areas between deeper channels. These 'subtidal flats' may host mussel beds of considerable size. Part of the beds in the western Dutch Wadden Sea occur in deeper channels north of the 'Afsluitdijk'.

Natural subtidal beds

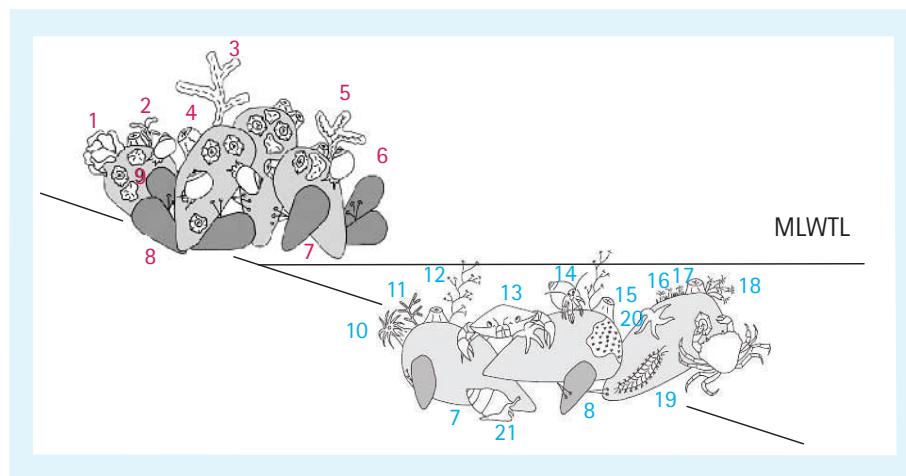
Knowledge of the ecology of natural subtidal mussel beds of the Wadden Sea is scarce. However, field investigations of mussel beds in the northern Wadden Sea revealed that intertidal and (shallow) subtidal mussel beds differ in (i) biogenic bed structure, (ii) species interactions and (iii) associated organisms (Saier, 2002). Structural differences include lower densities of mussels in subtidal than in intertidal beds (Saier, 2001; Saier, 2002; Buschbaum and Saier, 2001). Additionally, subtidal individuals are larger and less often heavily overgrown

by barnacles. The additional structure provided by barnacle overgrowth on intertidal mussel beds may enhance recruitment success of mussel spat up to 20-fold (Buschbaum, 2002a; Saier, 2001). In barnacle overgrown intertidal mussel beds, this facilitative mechanism is considered responsible for the comparatively high abundance of juvenile mussels.

Apart from structural differences, species interactions are different between intertidal and subtidal mussel beds. Periwinkles (*Littorina littorea*), for example, are abundant on intertidal mussel beds, where their grazing and bulldozing activity may be responsible for barnacle fluctuations (Buschbaum, 2000). In subtidal mussel beds, snail densities were much lower due to strong predation pressure and restriction of snail recruitment to the intertidal zone (Saier, 2000). Therefore, snails cannot be responsible for barnacle population dynamics in the subtidal zone. In the subtidal, barnacles are strongly preyed upon by abundant juvenile seastars (*Asterias rubens*), and adult green crabs (*Carcinus maenas*), rather than snails (Saier, 2001; Buschbaum, 2002b).

The total number and distribution of associated species differ between intertidal and subtidal mussel beds as well (Saier, 2002; Buschbaum and Saier, 2003). More than 150 species of algae and invertebrates live associated with mussel beds (Dittmann, 1990; Buschbaum, 2002a; Saier 2002). While some species occur in both tidal zones, many are limited to either intertidal or subtidal sites. For example, green and brown algae and periwinkles

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1 *Chondrus crispus* (Rhodophyta); 2 *Enteromorpha spec.* (Chlorophyta); 3 *Fucus vesiculosus* forma *mytilis* (Phaeophyta); 4 *Semibalanus balanoides* (Cirripedia); 5 *Bryopsis plumosa* (Chlorophyta); 6 *Littorina littorea* (Gastropoda); 7+8 *Mytilus edulis* (Bivalvia), 7 adult, 8 juvenile; 9 *Ralfsia verrucosa* (Phaeophyta); 10 *Metridium senile* (Anthozoa); 11 *Stylonema alsidii* (Rhodophyta); 12 *Obelia longissima* (Hydrozoa); 13 *Carcinus maenas*, adult (Crustacea); 14 *Eupagurus bernhardus* (Crustacea); 15 *Balanus crenatus* (Cirripedia); 16 *Asterias rubens*, juvenile (Echinodermata); 17 *Hydractinia echinata* (Hydrozoa); 18 *Bowerbankia sp.* (Bryozoa); 19 *Harmothoe sp.* (Polychaeta); 20 *Alcyonium mytili* (Bryozoa); 21 *Buccinum undatum* (Gastropoda), (after Buschbaum and Saier, 2003).

kles (*L. littorea*) are abundant in intertidal mussel beds while many red algae, hydrozoans, bryozoans and whelks (*Buccinum undatum*) are mainly restricted to subtidal mussel beds (Figure 8.5.2). The adult seastar (*Asterias rubens*) is restricted to the subtidal area as well, and may reach considerable numbers, occasionally causing substantial economic damage to subtidal culture lots.

These differences between intertidal and subtidal mussel beds are based on a case study of mussel beds near the island of Sylt in Schleswig-Holstein. It is also known from other parts of the Wadden Sea that natural subtidal mussel beds have their own characteristic and species-rich community provided that they are not disturbed by fishery (Buhs and Reise, 1997, and references therein). For most of the subtidal beds, however, no information is available.

Dolmer (2002) showed that in areas of Limfjorden where mussels were dredged there was a temporary reduction in the density of several animal groups, such as sponges, echinoderms, anthozoans, molluses, crustaceans and ascidians. Long-term effects were more difficult to show, although on one occasion a difference in species composition and density was observed between fished and not fished areas. Similar effects, however, could not be detected between experimentally fished and control areas in the fjord. Loss of benthic structural components as an effect of mussel dredging (Dolmer, 2002) may influence settling success and the survival of blue mussel spat.

Culture lots

In a way, mussels on culture lots can be considered a man-made type of subtidal mussel beds. However, the lifetime of this habitat is short, and the mussels on culture lots can be shifted around

by the mussel farmers to other beds, treated with barbed wire rolls for killing of seastars or lifted temporarily and treated with fresh water for the same purpose. After 1.5 to 2 years, the mussels on the culture lots are more than about 4.5 cm long, and ready for the market. What remains is a depleted bed, until it is seeded again.

On 50 ha of culture lot, a standing stock of 5,000 to 8,000 t of blue mussels may develop, while stocks at natural sites after surviving two years will reach 1,000 to 1,600 t at the most. Part of the seed and half-grown mussels from the Dutch Wadden Sea are exported to the southwest of The Netherlands for cultivation in the Eastern Scheldt, leading to an enhancement of blue mussel biomass in comparison with a situation without mussel culture (Bult *et al.*, 2004).

Subtidal mussels and shellfish-eating birds

Subtidal mussel beds constitute important feeding grounds for eider ducks. Ens and Kats (2003) mention that shellfish-eating birds may take about 25% of their food from intertidal areas in the Dutch Wadden Sea, which implies that shellfish consumption may be up to 20–30% of the total shellfish sublittoral stock (rough average 15–20%) (Brinkman and Smaal, 2003).

8.5.2.3 Status and exploitation of subtidal mussel beds

Netherlands

Status

The location of subtidal mussel beds and their biomass have been monitored annually since 1992, in order to regulate fishery for seed mussels needed by mussel farmers to stock their culture lots.

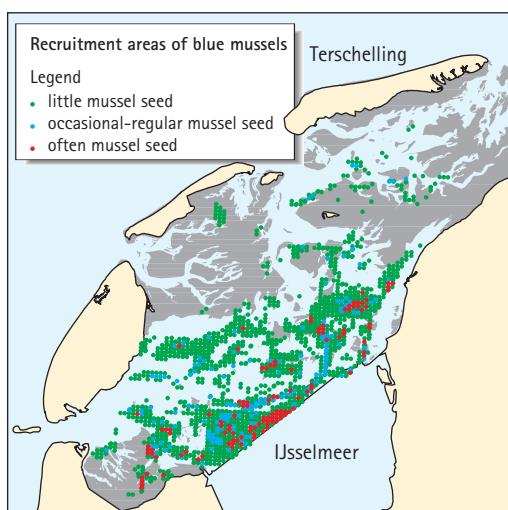
In The Netherlands, subtidal mussel beds occur in the westernmost part of the Wadden Sea, in an area of about 500 km² in the vicinity of the 'Afsluitdijk'. Figure 8.5.3 shows the area where subtidal young mussel beds occurred in the period 1992–2004. This area, with large subtidal mussel beds interspersed with the channels of the Marsdiep tidal basin and some relatively low intertidal flats that hardly emerge during low tide, is influenced by release of fresh water via sluices in the 'Afsluitdijk', causing more or less brackish conditions with salinity usually between 15 and 25 PSU. In the vicinity of the sluices salinities as low as about 10 do occur part of the time (Oost and Bokhorst, 2002). Net sedimentation in this area amounts to some mm per year (Hoeksema *et al.*, 2004).

Mussel fishery

All natural subtidal mussel beds in the western Dutch Wadden Sea are heavily exploited by mussel farmers, collecting young or half-grown mus-

Figure 8.5.3:

Recruitment areas of blue mussels (*Mytilus edulis*) in the western Dutch Wadden Sea. Average based on surveys in spring 1992–2004 (source: RIVO-CSO, Yerseke).



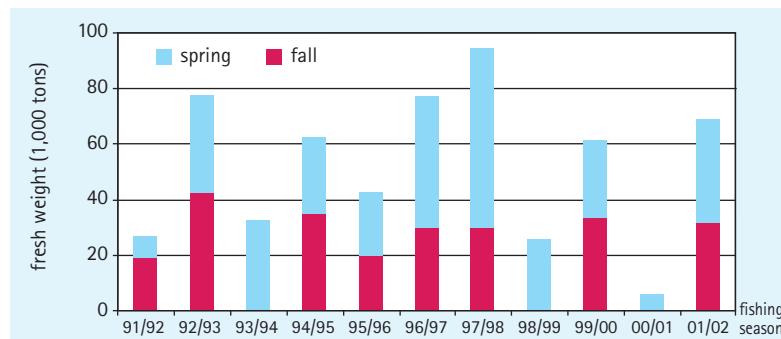


Figure 8.5.4:
Gross mussel seed capture
in the subtidal western
Dutch Wadden Sea per
season (Kamermans *et al.*,
2003).

sels ('seed mussels') to stock their culture lots (see below). There is no fishery on full grown wild mussels. Due to fluctuating recruitment success the total biomass is highly variable, ranging from less than 10,000 to about 80,000 t fresh weight during the period 1992–2002 (Bult *et al.*, 2004).

New spatfall occurs fairly often, leading to a moderate to good recruitment once every two years, and only little recruitment in the years in between. After 1990, however, recruitment appears to be less abundant than before, leading to lower maximal biomass values than in the period 1970–1990 (Brinkman and Smaal, 2003; Ens *et al.*, 2004). The amounts of seed mussels fished between 1990 and 2002 from the Dutch Wadden Sea and re-layed on culture lots ranged between 5,000 and 95,000 t per year (Figure 8.5.4).

There is no knowledge about the potential, age structure or biocoenosis of subtidal mussel beds in absence of fishery. A proposal has been made in the new Dutch fishery policy (2004) to establish some areas in which the development of undisturbed subtidal mussel beds can be studied (cf. chapter 2.5 'Fishery').

Niedersachsen

In some locations, natural subtidal mussel beds also occur in Niedersachsen. They are exploited for seed mussel fishery. Data about area and biomass is not available.

Schleswig-Holstein

Status

The subtidal mussel beds in Schleswig-Holstein can be subdivided into shallow beds, just below the low water line down to one or two m depth, mainly adjacent to intertidal beds, and deep beds below 2 or 3 m down to 25 m depth below the low water level.

The shallow type of subtidal mussel beds seems to be very stable; sites are covered more or less permanently with mussels in densities

comparable to intertidal beds (Figure 8.5.5). The beds consist of several age classes. No information about the extension of these beds exists because only parts of them are covered by aerial photo-

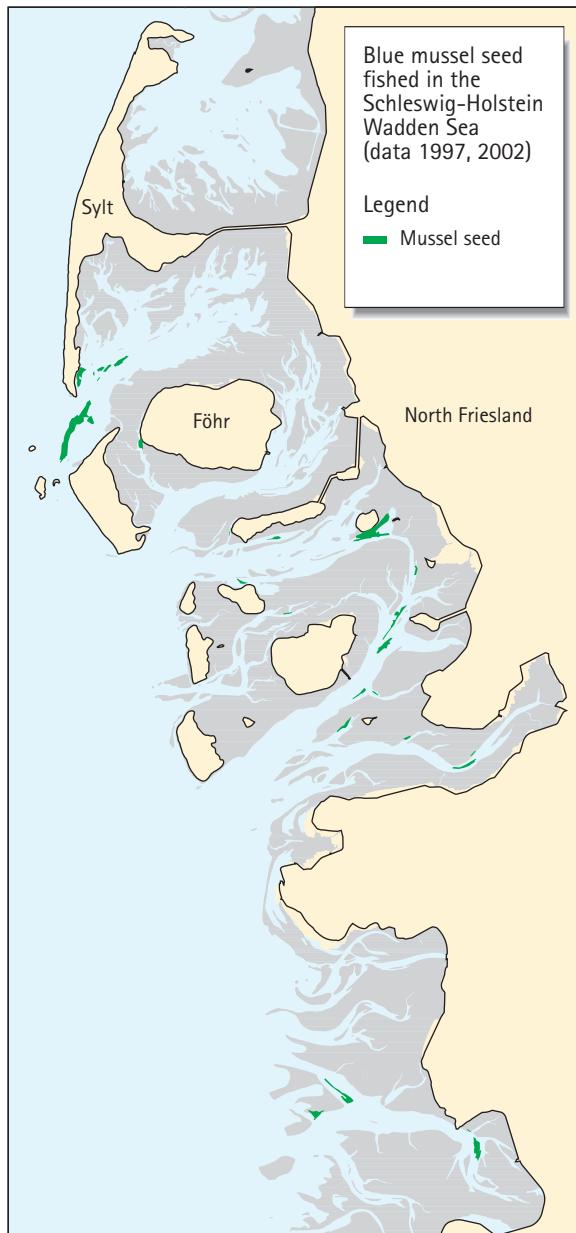


Figure 8.5.5:
Locations in Schleswig-Holstein (green) where
mussel seed was fished in
1997 and 2002,
indicating the most
important areas with
subtidal mussel beds. Data
taken from fishing activity
monitored by a blackbox

graphs or ground truth monitoring activities and because most of the time they are not used to fish seed mussels. It is believed that the stability of these beds is promoted by the absence of large seastars in the shallow subtidal.

The deep type of subtidal mussel beds show much more variation in biomass and occurrence than the shallow and intertidal beds. Extensive settlement in the deeper subtidal areas, mainly adjacent to the open sea, may in some years lead to the formation of large beds with high biomasses which, however, can be wiped out by the first strong gale. Losses due to predation by seastar (*Asterias rubens*) occur at all stages of development because seastars can take any size of mussel.

About a third of the subtidal area within the Wadden Sea proper of Schleswig-Holstein has been closed for seed fishery since 1997, but most sites where reasonable spatfall occurred in recent years were outside the closed areas. It is believed that within the areas open for fishery all deeper sites with mussel beds larger than some ha are found and fished. The size of the mussel population can be estimated by means of the black-box surveillance system in use since autumn 1997. Population structure is dominated by one or two year classes, older mussels are extremely scarce.

There is relatively little information about the subtidal stocks in the area closed for the seed fishery. Some sites are known but information about development, area covered, population density and structure is scarce. Surveys by Nehls (2003) in 1998–2002 within the closed areas revealed few

sites with subtidal mussel stocks. Investigations with a commercial mussel dredger in spring 2004 (Ruth, unpubl.) showed low densities of mussels ($<0.1 \text{ kg/m}^2$), nearly all of them belonging to the year class 2001. Further investigations of the dynamics of mussel stocks in the deeper part of the subtidal area are needed.

Reliable information about subtidal spatfall exists from 1989 onwards. Reasonably good spatfall took place in the years 1990, 1994, 1996, 1997, 1999 and 2001.

Mussel fishery

The amount of seed mussels taken by the mussel fishery in Schleswig-Holstein is shown in Figure 8.5.6. In Schleswig-Holstein, mussel seed fishing of new spatfall starts as early as possible, normally in July or early August at a mean mussel length of about 5 mm. Seed fishing is continued until late October / November when the mussels have reached mean length of about 35 mm.

A commercial mussel dredger fishing for seed mussels can sweep an area of about 10,000 m² in one hour, and the efficiency of the dredge is close to 100%.

Denmark

Status

The subtidal beds in the Danish Wadden Sea are much smaller than the area covered with intertidal mussel beds. The subtidal beds have covered an area of about 200 ha since the survey program began in 1986 (Munch-Petersen and Kristensen, 1987, 2001).

The main subtidal beds are situated in the Ho Bugt area. Some subtidal beds have disappeared and new ones have appeared either in the old places or in new ones. Subtidal beds are also found in Knude Deep and in Lister Deep. They are regularly exploited by fishery.

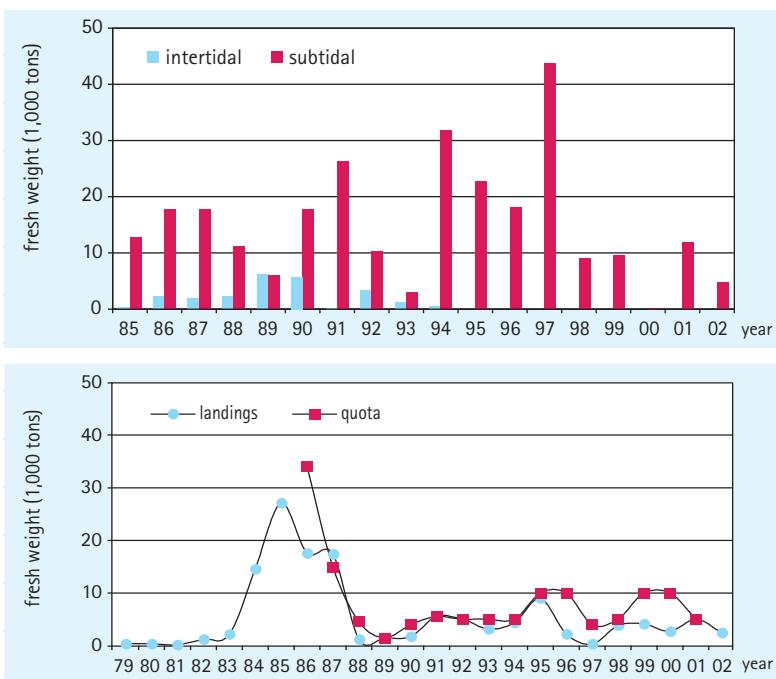
Mussel fishery

There are no culture lots in Denmark, so there is no fishing for seed mussels. As part of a government funded nature conservation project mussel seed was transplanted in August 2002 from Horns Reef to two minor places in the Danish Wadden Sea. The purpose was to re-establish old mussel beds lost several years ago due to fishing and to see if by transplanting mussels the establishment of new beds in these areas can be stimulated.

Export of seed mussels to The Netherlands and/or Schleswig-Holstein is prohibited, because, according to the Danish fishery regulation, no mussels below 5 cm in shell length may be fished, transported or landed. In landing, a by-catch of up to 10% weight of smaller mussels is allowed.

Figure 8.5.6 (top):
Amount of seed mussels fished in the intertidal and subtidal parts of the Wadden Sea of Schleswig-Holstein in 1985–2002 (Nehls and Ruth, 2004).

Figure 8.5.7 (bottom):
Annual quota and landings of blue mussels from the Danish Wadden Sea. Landings consist of subtidal mussels only (from: Kristensen and Pihl, 2003).



The subtidal beds in Ho Bight are regularly fished, with a quota set by the government. Since 1989, only limited fishing has taken place on subtidal mussel beds in the Lister Deep area. The total annual landings between 1990 and 2002 from the Danish Wadden Sea varied between 1,500 and 10,000 tons (Figure 8.5.7).

8.5.2.4 Culture lots

Culture lots are formed by relaying young, or half-grown mussels in an area where no natural mussel bed is present, but where good growing conditions exist for mussels that are big enough to resist the local water currents and withstand predation by shrimps and crabs. Culture lots are allotted to mussel farmers by the responsible authorities. Seeding of culture lots is usually done in autumn and spring. No culture lots are allowed in the Danish Wadden Sea.

Culture lots in The Netherlands

The total available area amounts to about 7,000 ha, of which about 4,000 ha is stocked with seed mussels. This area has changed little over the last decades. The location of the culture lots is indicated in Figure 8.5.8. The production at the culture lots in the Dutch Wadden Sea has tended to decrease since 1990 due to shortage of seed mussels. The biomass of mussels on these lots is estimated at 20-100 tons fresh weight per ha, including shell and retained water. The mean annual landings of mussels from these culture lots amounted to 37,000 tons in the period 1990-2000, varying between about 15,000 and 60,000 tons (Bult *et al.*, 2004). More information about annual landings is to be found in chapter 2.5 'Fishery'.

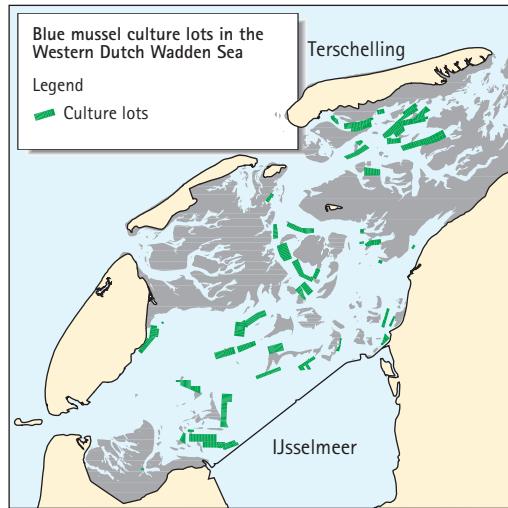


Figure 8.5.8: Culture lots in the Dutch Wadden Sea (source: RIVO).

Culture lots in Niedersachsen

Most culture lots in Niedersachsen are situated between Borkum, Juist and the mainland coast, and along the east side of the Jade and in the Jadebusen (Figure 8.5.9). Their total surface is about 1,300 ha; the proportion actually used changes from year to year.

The annual landings from these culture lots are generally about 7,500 tons, but with considerable annual variation ranging from almost zero to more than 15,000 tons (see chapter 2.5 'Fishery').

Culture lots in Schleswig-Holstein

Most of the culture lots in Schleswig-Holstein are mainly situated in the northern part of the area, between Pellworm and the Danish border (Figure 8.5.10). The maximum allowed area of all culture lots in 2003 in Schleswig-Holstein was 2,200 ha. This area used to be about 3,000 ha and will be reduced to 2,000 ha at the end of 2006. A maxi-

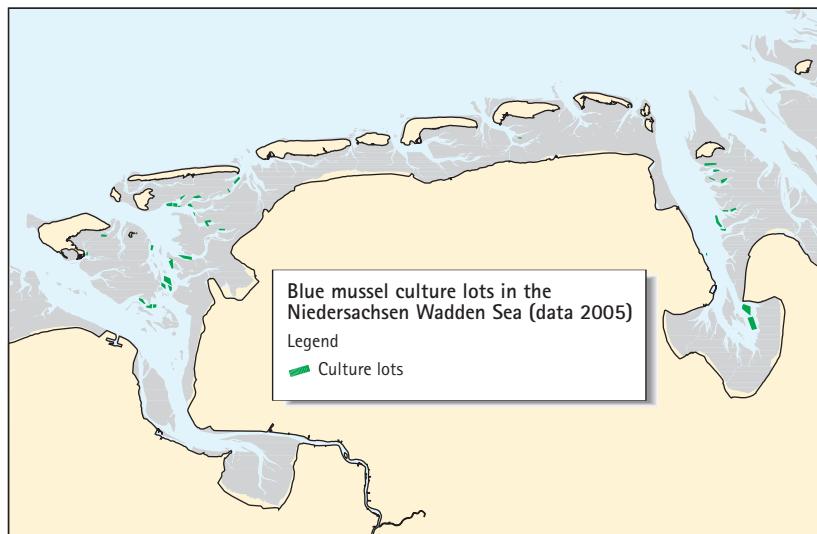
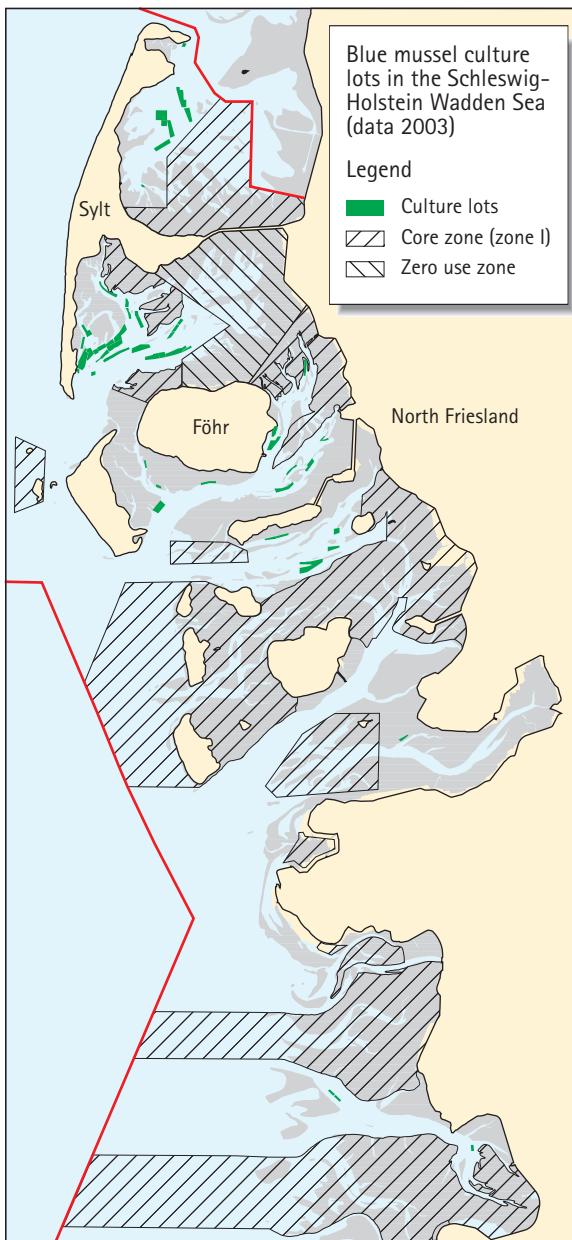


Figure 8.5.9: Location of mussel culture lots in Niedersachsen (source: Nationalparkverwaltung Niedersächsisches Wattenmeer).

Fig 8.5.10:
Mussel culture lots in the
Wadden Sea of Schleswig-
Holstein in 2003, (Nehls
and Ruth, 2004).



mum of about two third (1,400 ha) of the total surface can be used simultaneously, the remaining area being needed for replacing mussels e.g. in autumn from exposed to sheltered lots and vice versa in spring. The lots yield up to 200 t/ha, with an average not exceeding 70 t/ha. A new year class can be landed from the first of October of the following year onwards at medium sizes of about 45 mm, but the average lifetime of a year class is between 2 and 3 years (medium size >55 mm). Growth and meat content vary greatly between culture lots and years.

The landings of blue mussels in Schleswig-Holstein in 1985-2002 varied between about 5,000 and 42,000 tons per year (see chapter 2.5). As the market has not been saturated since 1989, this

variation is an expression of the availability of seed mussels in the preceding years. In turn, the availability of seed mussels is linked to the temperature in January - March; the probability of spatfall increases with decreasing winter temperatures (see chapter 3 'Climate').

Culture lots in Denmark

There are no culture lots in Denmark. All Danish blue mussels for human consumption are harvested from the natural mussel beds in the subtidal area.

8.5.2.5 Conclusions

Considerable areas with subtidal mussel beds exist in The Netherlands and Schleswig-Holstein in some years; relatively small areas are known in Niedersachsen and Denmark. The ecosystem of subtidal beds is potentially more diverse than on littoral beds, but further investigations are needed to provide better documentation.

The natural subtidal beds in The Netherlands are intensively exploited for mussel seed, so most mussels on these beds do not reach more than two years of age. The recruitment area has been more or less stable during the last 50 years, but the recruitment biomass tends to decrease since 1990.

The few natural subtidal mussel beds in Niedersachsen are used for mussel seed fishery, but further information is lacking.

In Schleswig-Holstein, about a third of the subtidal area where spatfall can be expected has been closed for seed fishing since 1997. Within the closed areas, apart from the shallow sites at the fringes of intertidal beds, no mussel population consisting of several age classes and with densities comparable to intertidal beds has been observed up to now; this situation might change after a good recruitment year. It is expected that more information about the occurrence and development of mussel populations in the deeper parts of the subtidal will be available in the years following the next severe winter.

In Denmark, mussels from subtidal beds are regularly fished when 90% of the mussels reach the legal size of 5 cm in shell length. The fishery is regulated by a strict quota.

The impact of mussel fishery on the ecological values of natural subtidal mussel beds is not well known.

Extensive areas of culture lots for mussel farmers are present in The Netherlands, Niedersachsen and Schleswig-Holstein. The size of these areas is more or less stable in The Netherlands (to-

tal: 7,000 ha; used: 4,000 ha) and Niedersachsen (max: 1,300 ha). In Schleswig-Holstein the area of culture lots has been decreasing since 1995 (total in 1994: about 3,000 ha, to be reduced to 2,000 ha in 2006; used: about two thirds).

Mussel beds on culture lots represent a man-made type of subtidal mussel bed with a considerable shorter lifespan, more disturbance (relying, removal of seastars and algae) and therefore with a less diverse associated fauna than natural mussel beds.

8.5.2.6 Target evaluation

With regard to the subtidal mussel beds, no evaluation of the Target is possible yet.

8.5.2.7 Recommendations

Protection of mussel beds (at stable sites) against fishery should not be restricted to the intertidal area but at least part of the subtidal beds should be protected as well.

Because of its ecological importance, the biotope 'subtidal blue mussel bed at stable sites' should be considered as a biological quality element for water in the relevant EC Directives.

Substantial investigation effort is needed to document the location and extent of subtidal mussel beds in the Wadden Sea and their structure and function.

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8.6 Fish



Ralf Vorberg
Loes Bolle
Zwanette Jager
Thomas Neudecker

Herring (Photo: R. Vorberg)

8.6.1 Introduction

Fish play an important role in the ecology of the Wadden Sea and the connected estuaries. They represent a taxonomic group of exceptionally high biomass, act as predators over different trophic levels and serve as prey for birds and marine mammals. Fish can drive ecological processes on a wide scale. For example, mass invasions of juvenile cod and whiting into the Wadden Sea, as repeatedly observed, can cause a short-term breakdown of the brown shrimp population with far-reaching effects for the ecological processes in the Wadden Sea area (Neudecker, 1990; Berghahn, 1996).

Fish can indicate changes in environmental conditions long time before these changes are physically measurable. The occurrence of Mediterranean species in the North Sea and Wadden Sea, as is illustrated by mullets (*Chelon labrosus*) and anchovies (*Engraulis encrasicolus*), is regarded as an effect of temperature change and discussed in the context of climate change (Cushing and Dickson, 1976; Beare *et al.*, 2004).

However, the importance of fish as a biotic factor in the ecology of the Wadden Sea is not accordingly recognized. Fish were neither considered in the Trilateral Wadden Sea Plan (1997) nor appear in the Trilateral Monitoring and Assessment Program (TMAG, 1997) to a sufficient extent. Trilateral targets regarding fish do not exist. In the Water Framework Directive (WFD) fish is a biological quality element in transitional waters, such as estuaries, but not in coastal water types, to which most parts of the Wadden Sea have been assigned.

The occurrence of fish in the Wadden Sea is

determined by the various characteristics of this water system, being open to the North Sea, controlled by strong tidal currents and influenced by inflowing rivers. Zijlstra (1978) provided a widely used classification system of the fish species occurring in the Wadden Sea. His approach already incorporated the ecological guild concept that is nowadays used in estuarine fish science (Elliott and Dewailly, 1995; Elliott and Hemingway, 2002). Accordingly, the fish can be classified as resident or near-resident species when they are tolerant to the dynamic abiotic environment and live in the area during their whole life. Other species are seasonal visitors to the area when they consider conditions suitable. Other species again use the Wadden Sea only as a passage during their migration from the sea to the rivers or the other way around. Together, these are known as diadromous species. And last but not least, juveniles of a number of marine species use the Wadden Sea as nursery area.

Two groups of fish can be distinguished: pelagic fish, occurring in the water column, and demersal fish, dwelling near the bottom. Abundance data for selected species (Table 8.6.1) will be presented, and possible trends discussed.

8.6.2 Surveys

Research and monitoring of fishes in the Wadden Sea is limited to few programs. Information used for this report is derived from routine monitoring programs in Germany and the Netherlands, which focus on bottom dwelling species (Boddeke *et al.*, 1969; Neudecker, 2001). Data for pelagic fish species was obtained from national monitoring

Table 8.6.1:
List of fish species
presented in this chapter.

Fish species	Scientific name	Functional group	Vertical distribution	Habitats Directive ¹⁾	Red list Status ²⁾	Data source ³⁾
Herring	<i>Clupea harengus</i>	marine juvenile	pelagic	-	MB	
Sprat	<i>Sprattus sprattus</i>	marine juvenile	pelagic	-	MB	
Anchovy	<i>Engraulis encrasicolus</i>	marine seasonal	pelagic	-	MB	
Smelt	<i>Osmerus eperlanus</i>	diadromous	pelagic	-	MB & MFS	
Twaite shad	<i>Alosa fallax</i>	diadromous	pelagic	Annex II, V	vulnerable	MB & MFS
Houting	<i>Coregonus oxyrinchus</i>	diadromous	pelagic	Annex II, IV	critical	MPS
Salmon	<i>Salmo salar</i>	diadromous	pelagic	Annex II, V, ⁴⁾	critical	MPS
Sea trout	<i>Salmo trutta</i>	diadromous	pelagic	-	endangered	MPS
Eelpout	<i>Zoarces viviparus</i>	resident	demersal	-	-	DFS, DYFS
Bull trout	<i>Myoxocephalus scorpius</i>	resident	demersal	-	-	DFS, DYFS
Five-bearded rockling	<i>Ciliata mustela</i>	resident	demersal	-	-	DFS, DYFS
Hooknose	<i>Agonus cataphractus</i>	resident	demersal	-	-	DFS, DYFS
Butterfish	<i>Pholis gunellus</i>	resident	demersal	-	-	DYFS
Sand goby	<i>Pomatoschistus minutus</i>	near-resident	demersal	-	-	DYFS
Plaice	<i>Pleuronectes platessa</i>	marine juvenile	demersal	-	-	DFS, DYFS
Sole	<i>Solea solea/vulgaris</i>	marine juvenile	demersal	-	-	DFS, DYFS
Dab	<i>Limanda limanda</i>	marine juvenile	demersal	-	-	DFS, DYFS
Flounder	<i>Platichthys flesus</i>	diadrom/resident	demersal	-	-	DFS, DYFS, MFS
Cod	<i>Gadus morhua</i>	marine juvenile	demersal	-	-	DYFS
Whiting	<i>Merlangius merlangus</i>	marine juvenile	demersal	-	-	DYFS
Eel	<i>Anguilla anguilla</i>	diadromous	demersal	-	-	DFS, DYFS, MFS
River Lamprey	<i>Lampetra fluviatilis</i>	diadromous	demersal	Annex II, V	endangered	MB & MFS
Three-spined stickleback	<i>Gasterosteus aculeatus</i>	diadromous	demersal	-	-	MFS

¹⁾ Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora.

²⁾ after Nordheim *et al.* (1996),

³⁾ Data source:

MB = Monitoring program in the Meldorf Bight (Germany) – 1991–2003,

DFS = Demersal Fish Survey in the Dutch Wadden Sea and Ems-Dollard (Netherlands-RIVO) – 1970–2003,

DYFS = Demersal Young Fish Survey in the German Wadden Sea (Germany) – 1974–2003,

MFS = Migratory Fish Survey in the Ems-Dollard estuary (Netherlands-RIKZ) – 1999–2001,

MPS = Management Plan for Salmonids in Danish rivers,

⁴⁾ only for freshwater.

projects in The Netherlands and Germany. Appropriate data from Denmark was not available, because no regular monitoring of fish has taken place in the Danish Wadden Sea since the 1960s.

8.6.2.1 Fish monitoring in Meldorf Bight and Hörnum Tief (Schleswig-Holstein)

In 1991, a fish monitoring program started in the Meldorf Bight using a stow net as standard sampling gear (Vorberg, 2001). The stow net, operated from an anchored vessel, reached from the water surface down to the bottom and was suitable to obtain quantitative data for pelagic fish (Breckling and Neudecker, 1994). Three sites in the Meldorf Bight were sampled once a year in August. In 1997–2001 additional samples were taken in June in order to get more insight in seasonal variations of the fish fauna. Since 2001, a second sampling location has been installed in the Hörnum Deep, south of the island of Sylt.

8.6.2.2 Demersal Fish Survey (The Netherlands–RIVO)

An important source of information about the fish fauna in the Wadden Sea is the Demersal Fish Survey (DFS). This survey was initiated in 1969

(Boddeke *et al.*, 1969) and covers the Dutch Wadden Sea and the Ems-Dollard estuary. Initially the survey was carried out in spring (April–May) and autumn (September–October), but since 1987 only the autumn survey has been continued. Sampling is carried out with a 3-m-beam trawl rigged with one tickler chain, a shrimp net and a fine-meshed cod-end (20 mm). Sampling is restricted to the tidal channels and gullies deeper than 2 m, because of the draught of the research vessel. All fish and brown shrimp in the catches were analyzed.

8.6.2.3 Demersal Young Fish Survey (Germany)

After The Netherlands had started their 'census of juvenile fish' in 1969 in the Dutch Wadden Sea as well as in offshore areas up to the Danish coast (Boddeke *et al.*, 1969), German scientists joined in from 1970 onwards (Boddeke *et al.*, 1970). However, comparable survey data for the entire German region is considered to be available only since 1974 and this has not yet been fully digitized.

The survey design was equivalent to the Dutch DFS except for the tickler chain that was omitted

in the DYFS because of the excessive catch of dead shells in many of the German stations (Rauck, pers.com.). Spring (April–May) and autumn campaigns (September–October) were kept for the entire period as were towing time (15-min.-hauls) and the areas investigated. Since 1985, the area coverage of the Schleswig-Holstein part of the DYFS changed somewhat, and some deeper stations further off-shore were included (Neudecker, 2001).

For this report, DYFS abundance index data ($n/1,000 \text{ m}^2$) was generally calculated on the basis of a mean towing distance of 1,400 m per haul with the 3-m-beam trawl. Length frequencies were used to discriminate age groups of commercially important species.

As data digitizing and error control has not been completed for all sub-regions, years and species in the DYFS, complete time series can only be presented for plaice, sole, cod and whiting for the autumn campaigns of the Schleswig-Holstein sub-region. All other data is given for all four sub-regions, viz. Husum (HUS), Büsum (BUS), Cuxhaven (CUX) and East Frisia (OF), and for the period 1999 to 2003.

8.6.2.4 Migratory Fish Survey (The Netherlands-RIKZ)

From 1999–2001 a survey was carried out in the Ems-Dollard estuary (Kleef and Jager, 2002) aimed at documenting the presence and abundance of diadromous fish species. This survey was undertaken as part of a project on the restoration of estuarine gradients and fish migration ('Gradiënten'). Sampling was carried out at two locations: Oterdum (near Delfzijl) in the middle part of the estuary, and Groote Gat, further upstream in the main channel of the Dollard (Groote Gat).

Monthly samples were obtained between February and December by applying stow nets with 16 mm mesh size in the cod-end during the flood and ebb period separately. The net opening covered the water column from surface to bottom, and both demersal and pelagic species were caught. The fish were sorted by species and the number of diadromous fish was counted directly or by taking sub-samples of the abundant species.

8.6.2.6 Management plan for salmonids (Denmark)

Since the 1980s, several studies have been conducted in Denmark to investigate the status of the last breeding population of the houting (*Coregonus oxyrinchus*). Danish authorities took responsibility to preserve this endangered diadromous species in the Wadden Sea and to design a man-

agement plan for achieving this goal (Jensen et al., 2003).

Recently, genetic methods helped to identify a remnant stock of 'true' Wadden Sea salmon (*Salmo salar*) in the Varde Å and Ribe Å. This population is very small, and a program of supportive breeding is now carried out to strengthen this stock. During the last decades, the water quality of the Danish rivers has greatly improved as has the knowledge of habitat demands and migratory obstacles for the salmon and sea trout (*Salmo trutta*). Nowadays, several attempts are being made to reintroduce Atlantic salmon to their previous habitats in several Wadden Sea rivers, the most important and most ambitious being the Rhine-salmon project. In Denmark, the government launched an action plan for salmon in 1997. The plan covers nine rivers, where attempts are being made to re-establish lost populations of Atlantic salmon. Of these nine rivers, five drain into the Wadden Sea.

8.6.3 Pelagic species

The compilation of pelagic fish data for this report is based on the results of the Dutch and German stow net fishery in the Ems-Dollard and Meldorf Bight respectively. Catch data for pelagic species from bottom-trawl monitoring was omitted, because this sampling gear is not suitable to provide quantitative data for pelagic fish species.

8.6.3.1 Marine juveniles

Herring and sprat

Herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) are the most abundant fish species in the pelagic of the Wadden Sea. Often both species occur side by side, building big shoals. As the Wadden Sea functions as a nursery for both species, the catches are dominated by juveniles of 5–10 cm length. Adults have to be regarded as visitors to the Wadden Sea. Herring abundance in the Meldorf Bight fluctuates heavily from year to year and no clear trend is detectable (Figure 8.6.1). In contrast, catch results for sprat in the Meldorf Bight indicate a continued decrease since 1995; an even more drastic decline is visible between 1999 and 2003 (Figure 8.6.2).

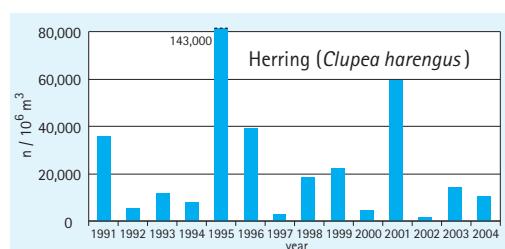
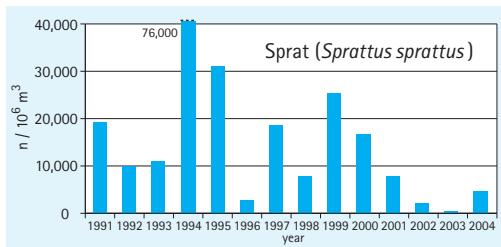


Figure 8.6.1:
Abundance of herring (*Clupea harengus*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

Figure 8.6.2:
Abundance of sprat (*Sprattus sprattus*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.



8.6.3.2 Marine seasonal Anchovy

In the first half of the 1990s, while sampling in August, anchovies (*Engraulis encrasicolus*) were caught in the Meldorf Bight program only occasionally. With the expansion of the program to include sampling in early June (1997–2002) an increasing abundance could be assessed (Figure 8.6.3). The anchovies caught were adults of 15–17 cm length and the females were ready to spawn. For the first time 0-group (= 'first year') anchovies of 4–5 cm were caught in 2003 explaining the unusually high abundance value of this year. Adult anchovies, about 20, were also caught in the Ems-Dollard near Oterdum in May 2001.

Figure 8.6.3:
Increasing abundance of anchovies (*Engraulis encrasicolus*) during fish monitoring in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches per year.

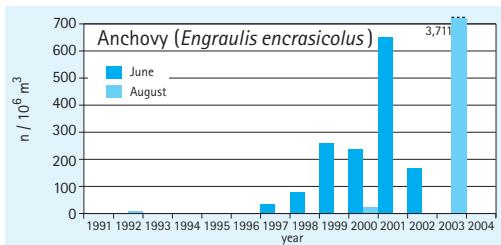


Figure 8.6.4:
Abundance of smelt (*Osmerus eperlanus*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

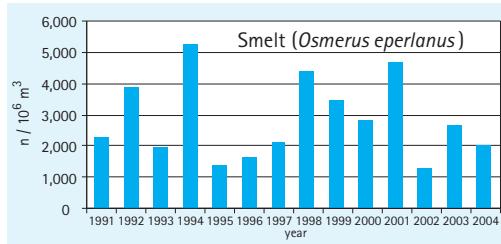
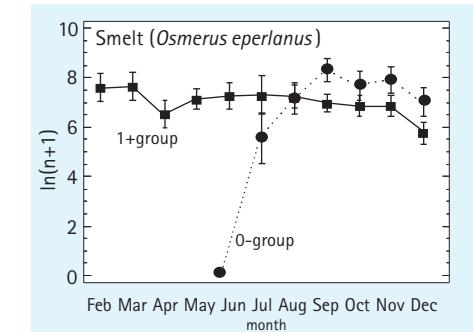


Figure 8.6.5:
Catch of smelt (*Osmerus eperlanus*) (in of the number standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval.



8.6.3.3 Diadromous species

The Dutch migratory fish survey in the Ems-Dollard estuary (1999–2001) revealed nine diadromous species. Monitoring in the Meldorf Bight revealed only seven diadromous species during 1991–2003. The presence of thinlipped mullet (*Liza ramada*) and sea lamprey (*Lampetra fluviatilis*) could not be proven in the Meldorf Bight.

Smelt

Smelt (*Osmerus eperlanus*) is an anadromous species which lives in the Wadden Sea and migrates into larger rivers for spawning in winter/spring. The data obtained from the Meldorf Bight shows that the abundance is more or less stable over the years (Figure 8.6.4). In the Ems-Dollard region, smelt historically spawned upstream in the Ems near Oldersum and apparently use the lower estuary and Dollard as a nursery. Individuals older than one year (1+group) were present during the whole year in fairly constant numbers. The 0-group appeared in the catches in June–July and reached maximum numbers in September (Figure 8.6.5). The large population of anadromous smelt that once occurred in the Zuiderzee converted to a land-locked form living in the IJsselmeer after the construction of the Afsluitdijk in 1932.

Twaite shad

The twaite shad (*Alosa fallax*) is a common Wadden Sea species entering the larger rivers in spring for spawning but is not limited to the Wadden Sea (Maitland and Hatton-Ellis, 2003). At the beginning of the 20th century, twaite shad occurred in high densities e.g. in the Elbe and Rhine rivers (Ehrenbaum, 1936; de Groot, 1989, 2002) and was of great commercial importance. In the following decades the species suffered from overfishing, stowing of rivers and loss of spawning habitat. In the Rhine system, twaite shad disappeared around 1966 following the closure of the Haringvliet. Twaite shad is listed in Annex II of the Habitats Directive (Kloppmann et al., 2003) and classified as vulnerable in the red list of marine fishes of the Wadden Sea (Nordheim et al., 1996).

The results obtained in the Meldorf Bight clearly indicate that twaite shad regularly occurs in the Wadden Sea (Figure 8.6.6). Juveniles especially are caught in high densities. Exceptionally high numbers of individuals of 6–9 cm length were caught in 2003. Adults of 30–40 cm frequently appear in the catches of the commercial stow net fishery in the Elbe (Rübcke, pers. comm.).

In the Ems-Dollard, twaite shad showed differing patterns of density and age composition over the years. In 1999, twaite shad suddenly became abundant in the catches in August and a

relatively high density continued up to November (Figure 8.6.7). The individuals caught in August were about 8 cm long, and increased to 11 cm in November. De Groot (1992) gives mean lengths of 6 cm after 6 months and 10–13 cm after one year. Twaite shad in the Elbe reached a mean length of over 10 cm at the end of their year of birth (Thiel *et al.*, 1996). On the basis of the length observed in the Ems-Dollard, it is assumed that the twaite shad caught in autumn of 1999 belonged to the 0-group. They returned in May 2000 at about the same density level and length as was observed at the end of 1999. In 2000, the numbers steadily decreased to a low level that was maintained during 2001. In autumn 2000 and 2001, no 0-group twaite shad were observed in the stow nets. Adult twaite shad are sporadically caught by professional fishermen in the Mouth of the Dollard (Westerhuis, pers. comm.).

Houting

A hundred years ago, houting (*Coregonus oxyrinchus*) was common and widespread throughout the Wadden Sea. This anadromous species leaves the Wadden Sea in autumn to spawn in larger fresh-water courses. Today, houting is regarded almost extinct in the Netherlands. No houting were caught in the migratory fish survey in the Ems-Dollard, and only very few specimens were encountered in a fyke monitoring near the Afsluitdijk in the western Dutch Wadden Sea (Tulp *et al.*, 2002). In Germany there is only a tiny population maintained by a release program in the little river Treene, a tributary of the Eider. Houting is listed as priority species in Annex II of the Habitats Directive (Kloppmann *et al.*, 2003) and is classified as critical in the red list of the trilateral Wadden Sea area (Nordheim *et al.*, 1996).

From 1987 until 1992 large numbers of fry were released in order to re-establish the houting in the Danish watercourses discharging into the Wadden Sea. After the releases of fry were discontinued only the population in the Vidå remained fairly stable, indicating a self-reproducing population. This made the Danish authorities to launch a comprehensive management plan to improve the overall conditions for the houting (Jensen *et al.*, 2003). Apart from releases of fry additional measures are planned, e. g. setting up fish passages and creating new spawning and nursery areas.



Twaite shad
(Photo: Z. Jager)

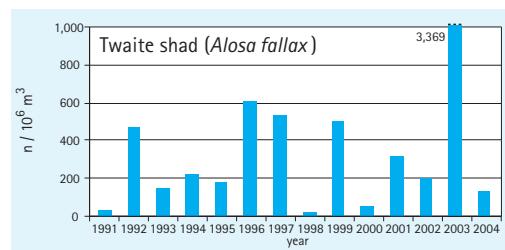


Figure 8.6.6:
Abundance of twaite shad (*Alosa fallax*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

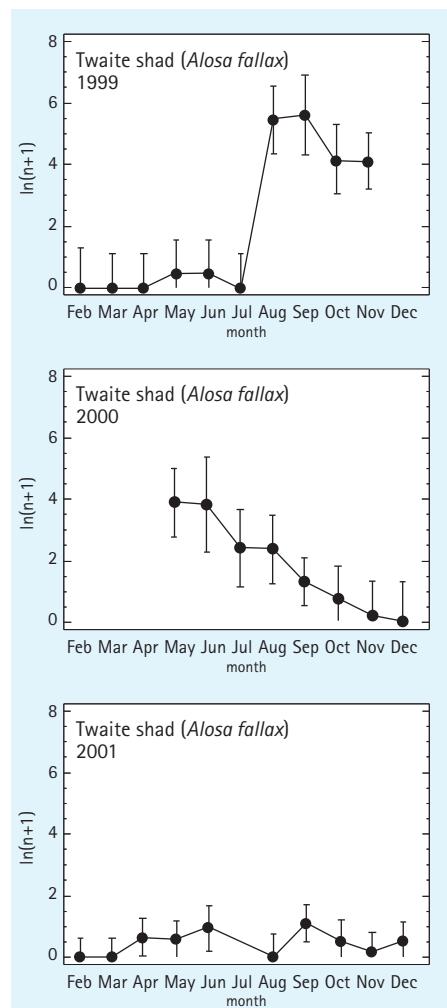


Figure 8.6.7:
Catch density of twaite shad (*Alosa fallax*) ($\ln(n+1)$ of the number standardized per 100 m² of net opening per tide) in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval.

Salmon and sea trout

The rivers flowing into the Wadden Sea used to be inhabited by large populations of Atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta*). Salmon is listed in Annex II of the Habitats Directive (only for fresh water) and is classified as critical in the red list of the trilateral Wadden Sea area (Nordheim *et al.*, 1996).

Salmon mainly used the Wadden Sea as a migratory pathway to the feeding grounds in the North Atlantic and on the way back to spawn in their natal rivers. Sea trout use the Wadden Sea also as a feeding area, spending a significant proportion of their life here. Salmon and sea trout used to be important species for the coastal commercial fishing in Denmark, Germany and The Netherlands, but man-made changes to the rivers have greatly impaired the conditions for these migratory fish and commercial catches are now negligible. Due to pollution, weirs, hydropower development and habitat destruction, the Atlantic salmon disappeared from all the rivers draining into the Wadden Sea during the last century. The only exception was the salmon in the Danish Skjern Å, located on the very Northern boundary of the Wadden Sea. In the Ems-Dollard, a few salmonid specimens were caught in spring 2001 near Oterdum, being mostly juveniles of 20–30 cm length; one adult of 51 cm was caught in August 2000. Stocking of salmonid fry in the Leda, tributary of the Ems, has been carried out since 1992 (Brumund-Rüther, pers. comm.).

State-of-the-art methods in supportive breeding, stocking and habitat improvement, along with increasing public awareness about the importance of migratory salmonids, gives hope for the future of salmon in the Wadden Sea, especially because co-operation between Danish, German and Dutch researchers and managers resulted in the possi-

bility to use offspring from Skjern Å salmon for a future stocking program in Germany. The salmon from Skjern Å are much more closely related to the now extinct Rhine salmon than the foreign stocking material used so far in the Rhine and Elbe, and thus will hopefully be better able to survive and adapt to the conditions in the Rhine and the other rivers where they are being re-stocked.

Sea trout are still present in numerous rivers and streams in the Wadden Sea area, but in general these populations have also declined during the last century due to human activities. Sea trout is classified as endangered in the red list of the trilateral Wadden Sea area (Nordheim *et al.*, 1996).

As sea trout spend most of their time feeding in the coastal areas, a major problem has been the by-catch of juveniles (smolt and post-smolts) in commercial fishing gear, especially pound nets, targeting eel and herring in spring. Legal and illegal gillnet fishing in the near shore areas have also been reported to cause high mortality among adult sea trout and salmon. Recent regulation of these types of fisheries have led to higher survival of both trout and salmon juveniles.

8.6.4 Demersal species

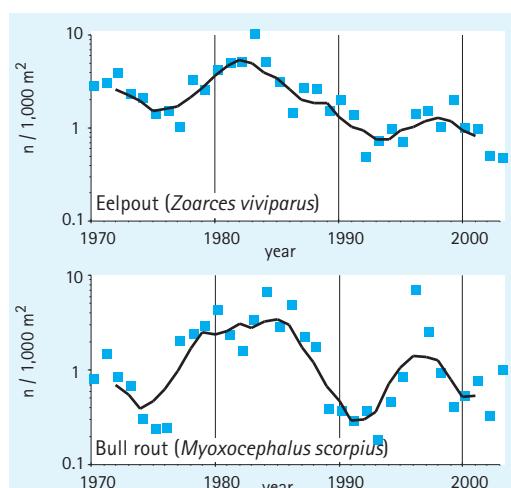
8.6.4.1 Residents

Eelpout and bull rout

Eelpout (*Zoarces viviparus*) and the bull rout (*Myoxocephalus scorpius*) are both typical resident species, i.e. they stay in the Wadden Sea during their whole life cycle. Both species are common inhabitants of the Wadden Sea, found particularly in the tidal channels in the vicinity of structures providing shelter such as mussel beds (de Jonge *et al.*, 1993). Most of the estuarine residents have demersal eggs and some form of parental care. Bull rout males guard their eggs and eelpout gives birth to fully developed juveniles (ovoviparous), which is considered an extreme form of parental care (Zijlstra, 1978; Fonds *et al.*, 1989). The limited dispersal during the egg, larval and adult life phases make these species suitable indicators of small-scale changes in the environment.

Eelpout and bull rout show similar trends in abundance in the Dutch Wadden Sea (Figure 8.6.8). The abundance of both species increased in the late 1970s and the highest catch rates were observed in the early 1980s. Thereafter, the abundance decreased until 1992–93, increased until approximately 1997–98 and then decreased again. Present catch rates are significantly lower than in the early 1980s. Similarly low catch rates (mostly <1 specimen/1,000 m²) were found in the differ-

Figure 8.6.8:
Catch rates of eelpout (*Zoarces viviparus*) (a) and
bull rout (*Myoxocephalus scorpius*) (b) in the Dutch
Wadden Sea (DFS-data):
the annual mean (symbols)
and the 5-year running
mean (solid line).



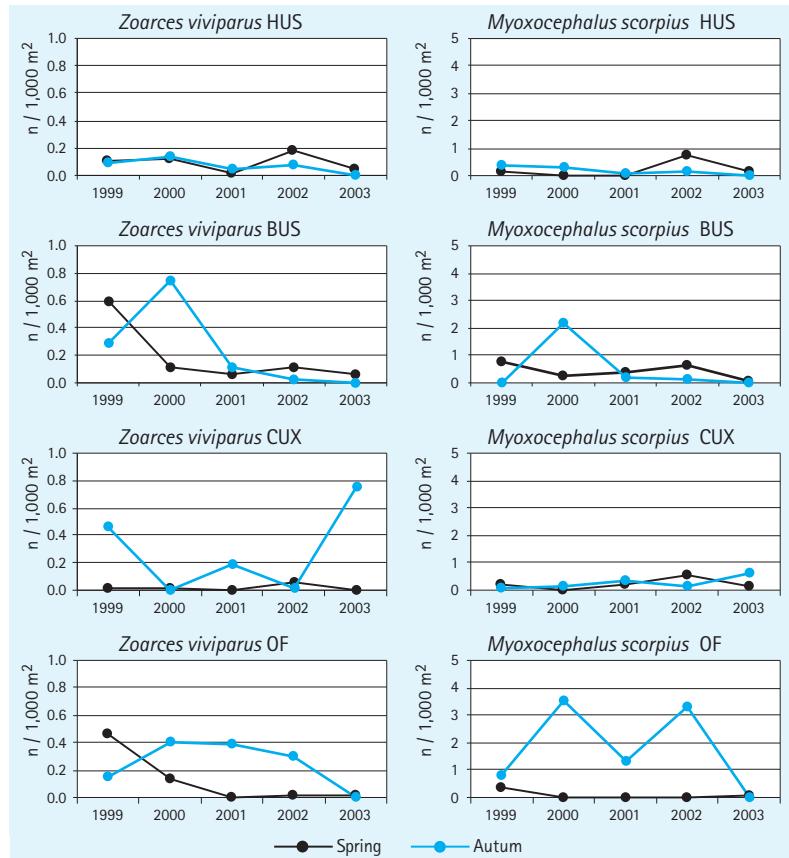


Figure 8.6.9:
Catch rates of eelpout (*Zoarces viviparus*) (left) and bull rout (*Myoxocephalus scorpius*) (right) in the DYFS for the years 1999 to 2003 for the four German Wadden Sea regions: HUS = west and north of Husum, BUS = west of Büsum, CUX = near Cuxhaven, Elbe estuary, OF = East Frisia north and south of the islands of Langeoog and Baltrum

ent parts of the German Wadden Sea (Figure 8.6.9).

The similarity in the trends and the fact that both species are associated with hard substrates suggests that the fluctuations may be related to variations in the availability of suitable habitat. In the 1999 QSR this relationship was crudely examined and it was argued that the occurrence of blue mussel beds may influence the spatial distribution of eelpout and bull rout, but cannot explain the observed trends in time. De Boer *et al.* (2001) examined for various species the correlation between catch rates and the distance to mussel beds, but neither eelpout nor bull rout showed a significant correlation. A similar up-and-down pattern for eelpout and bull rout catch rates as found in the Dutch Wadden Sea was found by Tiews (1990) and Tiews and Wienbeck (1990) in their analysis of by-catch data from the German brown shrimp fishery in the Wadden Sea for the period 1954–1988.

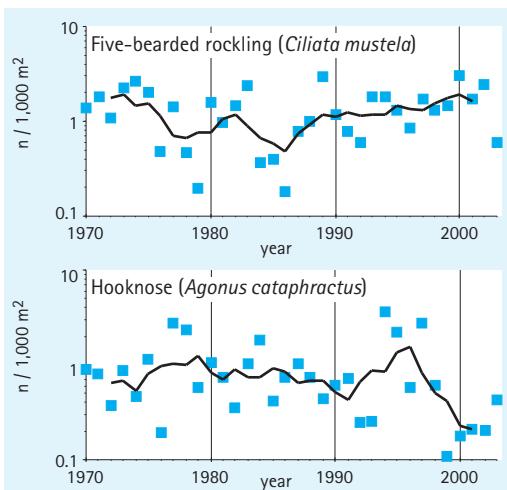
Also for bull rout, Dutch DFS and German by-catch data shows high values in the early 1980s and a decrease around 1990, in Germany at least for the Elbe estuary and an East Frisian region, while near Büsum there was a continuous fluctuation up and down over 50 years of sampling with a clear seasonality visible from the by-catch sam-

ples. So, the low level of bull rout in recent years seems to be within the natural range as well. A sign of a possible increase of the population was observed during the 2004 DYFS spring campaign in Germany (Neudecker, unpublished data).

Five-bearded rockling and hooknose

Five-bearded rockling (*Ciliata mustela*) and hooknose (*Agonus cataphractus*) are classified as (near) residents because they spend most of their life in the Wadden Sea. However, this classification is to some extent arbitrary. Although several authors (Zijlstra, 1978; de Boer *et al.*, 2001; Elliott and Hemingway, 2002) characterized hooknose as a true resident species, Fonds (1978) described a seasonal movement out of the Wadden Sea in winter. Five-bearded rockling leaves the Wadden Sea to spawn in deeper water (Zijlstra, 1978) and is therefore classified by some authors as a marine seasonal migrant (de Boer *et al.*, 2001; Elliott and Hemingway, 2002). Both species are common in inshore waters. Five-bearded rockling is a littoral species probably only moving to the sub-littoral during spawning, whereas hooknose is widely distributed throughout the southern North Sea (Witte *et al.*, 1991, Knijn *et al.*, 1993). Both species are important predators of brown shrimp (Tiews, 1978), but they also prey on other invertebrates and gobies

Figure 8.6.10:
Catch rates of five-bearded rockling (*Ciliata mustela*) (a) and hooknose (*Agonus cataphractus*) (b) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).



(Kühl, 1961; Badsha and Sainsbury, 1978; de Boer et al., 2001).

The catch rates of five-bearded rockling and hooknose in the Dutch Wadden Sea are plotted in Figure 8.6.10. Large annual variations in abundance estimates are observed, but there are no clear trends over longer time periods. Nor was any trend observed for five-bearded rockling in the time series from German by-catch data (Tiews, 1990). Catch rates in the recent DYFS are of similar magnitude as in the Dutch DFS, though with

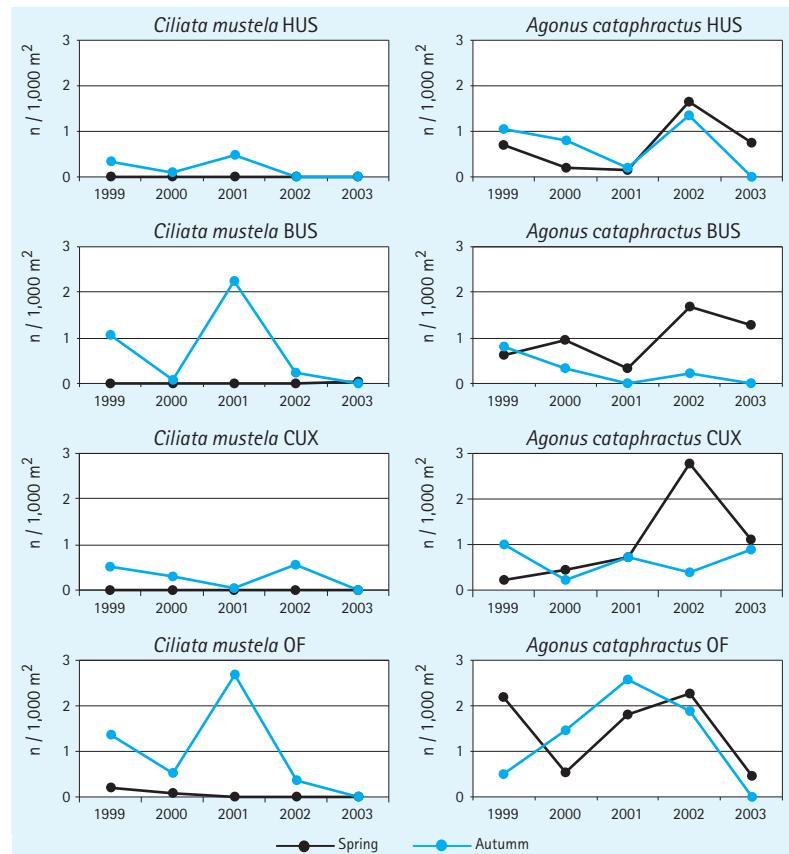
catch rates being considerably higher in autumn than in spring (Figure 8.6.11).

For hooknose the first two decades of the by-catch program show higher values for the Büsum area, however, in the Elbe estuary (CUX) the opposite seems to occur. The same is valid for the seasonal pattern derived from the by-catch samples, where a maximum can be seen in summer in the Elbe region and lowest values for the same period little further north near Büsum (Neudecker et al., 1999). In East Frisia (OF), unusually high numbers were found in the 1970s in the by-catch time series (Tiews and Wienbeck, 1990), but a general trend up to the present cannot be seen. The recent DYFS catch rates for hooknose are similar as those in the Dutch Wadden Sea for the last five years and in the same range as 25 years before. The data in Figure 8.6.11 suggests a regional trend of decreasing abundance from East Frisia (OF) towards the northern part of the German Wadden Sea.

Butterfish and sand goby

Two further species common to shallow coastal waters may be mentioned, butterfish (*Pholis gunellus*) and sand goby (*Pomatoschistus minutus*). Butterfish was present in 30–90% of all DYFS campaigns in low numbers, while the short lived

Figure 8.6.11:
Catch rates of five-bearded rockling (*Ciliata mustela*) (left) and hooknose (*Agonus cataphractus*) (right) in the DYFS for the years 1999 to 2003 for the four German Wadden Sea regions: HUS = west and north of Husum, BUS = west of Büsum, CUX = near Cuxhaven, Elbe estuary, OF = East Frisia north and south of the islands of Langeoog and Baltrum.



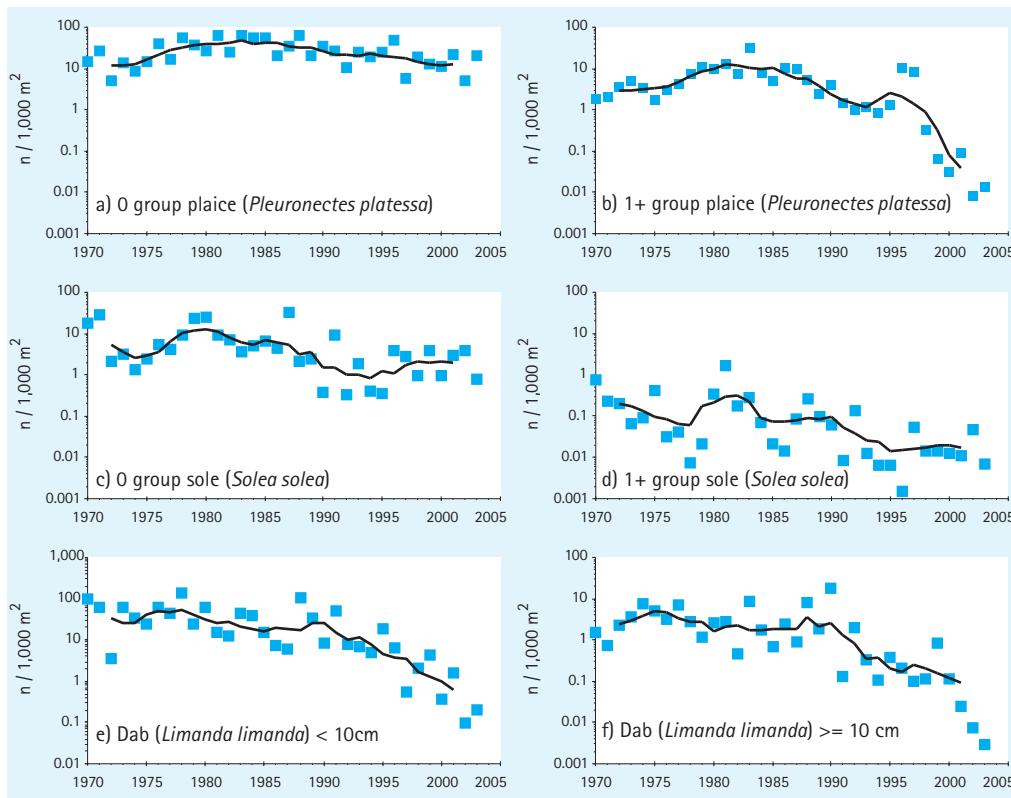


Figure 8.6.12: Catch rates by age group or size class of plaice (*Pleuronectes platessa*) (a-b), sole (*Solea solea*) (c-d) and dab (*Limanda limanda*) (e-f) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).

sand goby occurred in all catches with catch rates up to 30 per 1,000 m². There is no trend visible in the DYFS data (1999–2003). The fish by-catch time series shows no trend for butterfish either, but does show a decline of gobies over the 40 year period from 1955 to 1994 for the Büsum area as well as in the Elbe estuary (Neudecker *et al.*, 1999). This decline seems to be a result of the observed shift of fishing grounds of the German shrimping fleet towards deeper waters rather than a real population decline (Neudecker, 1999). An analysis of data for butterfish and sand goby from the Dutch Wadden Sea was not made.

8.6.4.2 Marine juveniles Flatfish

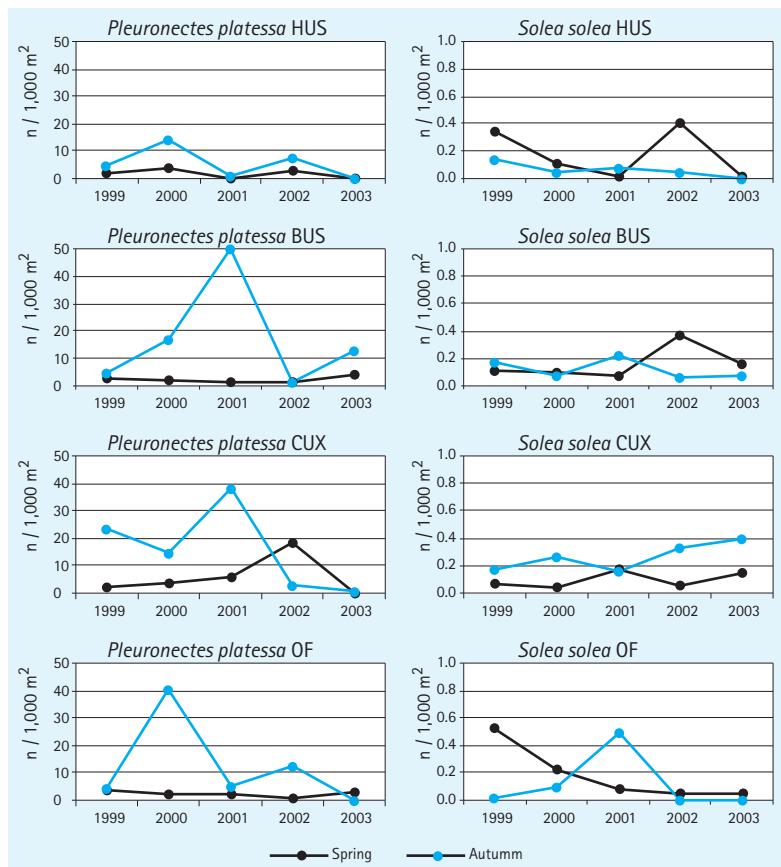
The Wadden Sea is an important nursery area for sole (*Solea solea*) and especially for plaice (*Pleuronectes platessa*) (Zijlstra, 1972, Beek *et al.*, 1989). Both fish species spawn in the North Sea and their pelagic eggs and larvae are transported to the coastal and estuarine nurseries by tidal currents (Talbot, 1976; Rijnsdorp *et al.*, 1985). After entering the Wadden Sea the pelagic larvae undergo metamorphosis and settle on the tidal flats. Dab (*Limanda limanda*) also spawns in the North Sea and also has pelagic eggs and larvae. After metamorphosis, post-larvae settle outside the Wadden Sea in sub-tidal coastal waters. Later, in its first

year of life, the dab moves into the tidal channels of the Wadden Sea (Bolle *et al.*, 1994). All three flatfish species leave the Wadden Sea before their first winter as juveniles. A part of the population re-enters the Wadden Sea in their second year of life, and most of them permanently leave the Wadden Sea before their second winter as juveniles.

For these three species, trends in abundance from the Dutch DFS have been examined separately for two age groups: the 0-group and the 1+ group. As for dab age determinations are only available for a limited number of years, 2 size classes were distinguished which roughly correspond to the 0-group and the 1+ group. The abundance of 0-group plaice, 0-group sole and 1+ group sole has declined since 1980 (Figure 8.6.12 a, c, d). Although significant, these trends are far less striking than the severe decline in abundance of 1+ group plaice, small dab and larger dab (Figure 8.6.12 b, e, f).

Similar low levels of abundance are apparent in the German Wadden Sea regions in the period 1999–2003, especially for plaice and sole, regardless of possible regional differences (see Figure 8.6.13). Plaice is least abundant in the northernmost region near Husum and shows decreasing abundances towards the more southern parts of

Figure 8.6.13
Catch rates of plaice (*Pleuronectes platessa*) (left) and sole (*Solea solea*) (right) in the DYFS for the years 1999 to 2003 for the four German Wadden Sea regions: HUS = west and north of Husum, BUS = west of Büsum, CUX = near Cuxhaven, Elbe estuary, OF = East Frisia north and south of the islands of Langeoog and Baltrum.



the Wadden Sea. Plaice abundance is highly variable; exceptionally strong year classes occurred in 1983, 1996 and 2001 (Figure 8.6.14, autumn data). These strong year classes, however, are not always reflected in the abundances in the spring survey of the following year, which may be due to time shifts – even small ones – in sampling and/or annual climatic variations. The by-catch time series data of Tiews (Neudecker *et al.*, 1999) clearly shows the seasonal pattern with a summer peak

and a continuous decrease towards winter, but a variable though slight increase of plaice by-catch for the period from 1955 to 1994. The latter increase, however, is in contradiction to the more recent and shorter DYFS data set, which may have been caused by changes in the commercial fishing pattern (change to more offshore fishing grounds) and survey design due to different charter vessels (larger ones since 1984).

Sole may also show outstanding year classes as in 1982 or 1987 (Figure 8.6.15). This species is less common, with a preference for the deeper parts of the German Wadden Sea. Since the good year class of 1996, densities have remained rather low.

Dab exhibited rather low densities (<5 per 1,000 m²) in all German regions except for the East Frisian part, where densities of 10–20 per 1,000 m² prevail in 1999–2001 equaling the densities in the Dutch Wadden Sea.

The decreasing trends observed in sole and 0-group plaice in the Dutch Wadden Sea may partly be related to changes in stock size. The spawning stock size of North Sea plaice and sole is currently considered to be below safe biological limits (ICES, 2004a), which poses the risk of impaired recruitment. However, the magnitude of decline in the

Figure 8.6.14:
Catch rates of plaice (*Pleuronectes platessa*) in the DYFS for the years 1974 to 2003 for the Schleswig-Holstein region from spring and autumn campaigns (AG = Age Group).

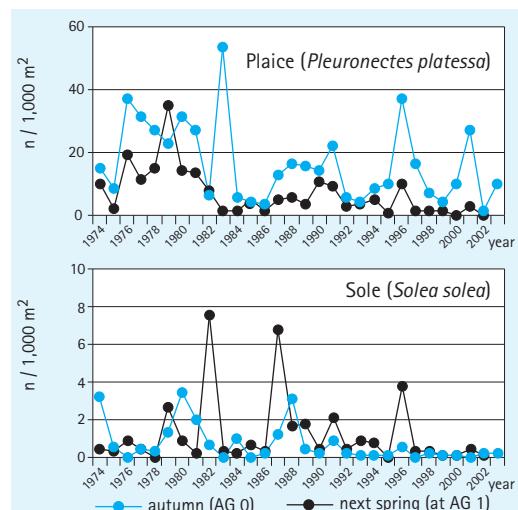


Figure 8.6.15:
Catch rates of sole (*Solea solea*) in the DYFS for the years 1974 to 2003 for the Schleswig-Holstein region from spring and autumn campaigns (AG = Age Group).

1+ group (Fig. 8.6.12) cannot be explained by changes in stock size. Examination of all demersal survey data (Beam Trawl Survey, Sole Net Survey and coastal Demersal Fish Survey) shows an offshore shift in the distribution of juvenile plaice in recent years (Grift *et al.*, 2005.; Pastoors *et al.*, 2000). This indicates that the change in distribution is not caused by local changes within the Wadden Sea. Various causal factors have been suggested, such as rise in temperature, lower levels of eutrophication and decline in turbidity. However, no conclusive evidence is available yet. The present data on shift in distribution suggests that plaice is less sensitive than dab and more sensitive than sole to whatever the causal factors may be. Taking into account the temperature tolerance of these species (Fonds *et al.*, 1992; Fonds, pers. com.), there is ground for the hypothesis that a temperature rise is contributing to the shift in distribution of juvenile flatfish, resulting in a decreased abundance in the Wadden Sea.

Cod and whiting

Cod (*Gadus morhua*) and whiting (*Merlangius merlangus*) are fish of the North Sea rather than of the Wadden Sea. As 0- or 1-group predators they may, however, have an enormous impact on the fauna of the Wadden Sea. It happens that in certain years uncountable numbers aggregate near or in the tidal channels decimating every other species available in eatable size (Berghahn, 1996; Neudecker, 1990; Neudecker *et al.* 1999; Tiews, 1978). In Figure 8.6.16, these mass aggregations of whiting are illustrated.

Cod showed similar invasions in 1970, to lesser extent in 1977, 1978 and for the last time in 1983 (Neudecker *et al.*, 1999). Since then stocks of cod have decreased dramatically and young cod are now rare also in the catches of the DYFS monitoring program (Figure 8.6.17).

8.6.4.3 Diadromous species

Flounder

Flounder (*Platichthys flesus*) spawns in the North Sea and the larvae enter the estuary in April–May using selective tidal transport (Jager, 1999), settle on the tidal flats and use the estuary as a nursery. Small flounders are found in the Wadden Sea but they also inhabit fresh water such as the lower reaches of rivers. Therefore, flounder has been classified as a resident species by some authors (Zijlstra, 1978; Elliott and Hemingway, 2002) and as a diadromous species by others (Duncker and Ladiges, 1960; Vorberg and Breckling, 1999).

In the Ems-Dollard estuary flounder reached catchable sizes for the stow net employed from

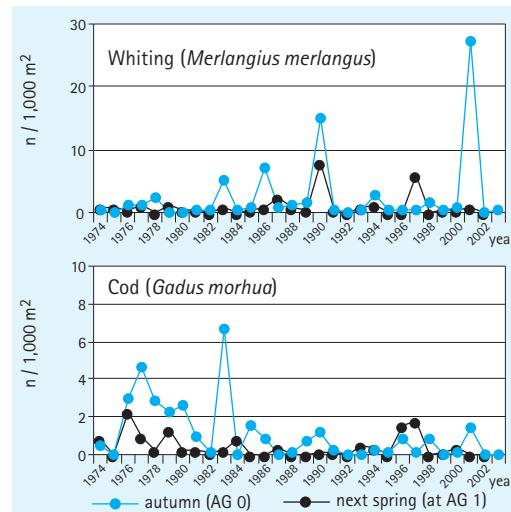


Figure 8.6.16:
Catch rates of whiting (*Merlangius merlangus*) in the DYFS for the years 1974 to 2003 for the Schleswig-Holstein region from spring and autumn campaigns (AG = Age Group).

Figure 8.6.17:
Catch rates of cod (*Gadus morhua*) in the DYFS for the years 1974 to 2003 for the Schleswig-Holstein region from spring and autumn campaigns (AG = Age Group).

May onwards and the 0-group reached maximum numbers in September–October and then decreased again. 1+-flounders were most abundant during May–July and then decreased (Figure 8.6.18). Long-term data as derived from the DFS do not show a clear trend over recent decades. Mean abundance fluctuates heavily from year to year whereas the 5-year running mean is more or less stable (Figure 8.6.19).

Yearly fluctuations are also found in the German DYFS and by-catch data. Flounder is present in the German Wadden Sea with an overall average density of ca. 1 per 1000 m² (Figure 8.6.20), lower numbers are present the northern part, and higher numbers in the wider vicinity of the Elbe to Ems region.

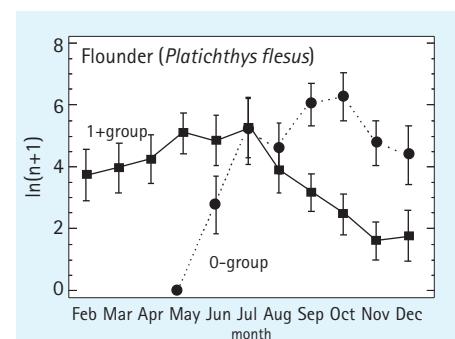


Figure 8.6.18:
Catch of flounder (*Platichthys flesus*) (ln of the number standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

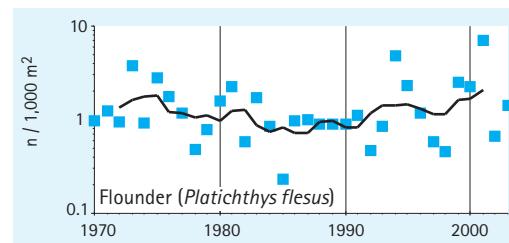


Figure 8.6.19:
Catch rates of flounder (*Platichthys flesus*) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).

Figure 8.6.20
 Catch rates of flounder (*Platichthys flesus*) in the DYFS for the years 1999 to 2003 for the four German Wadden Sea regions: HUS = west and north of Husum, BUS = west of Büsum, CUX = near Cuxhaven, Elbe estuary, OF = East Frisia north and south of the islands of Langeoog and Baltrum.

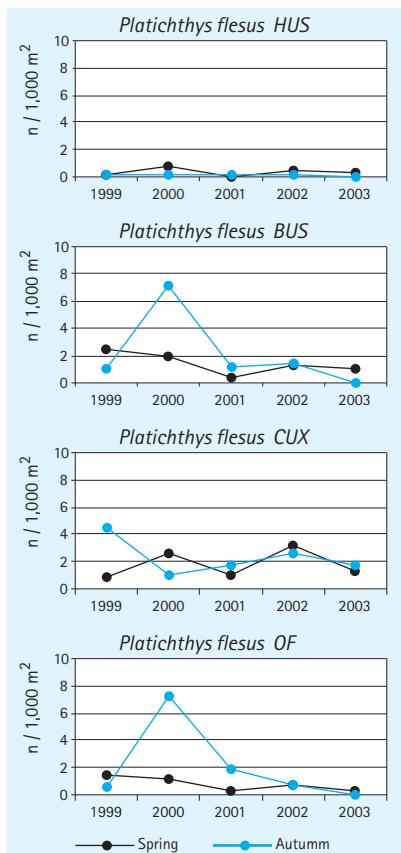


Figure 8.6.21:
 Catch of eel (*Anguilla anguilla*) (ln of the number standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

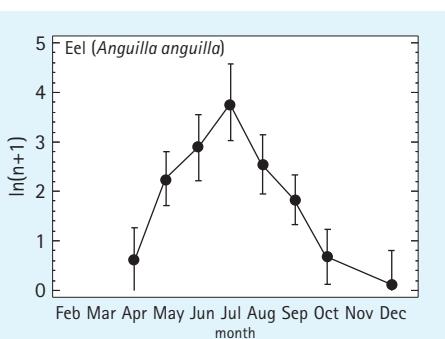
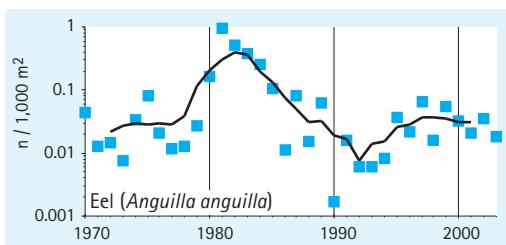


Figure 8.6.22:
 Catch rates of eel (*Anguilla anguilla*) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).



Eel
 Eel (*Anguilla anguilla*) spawns in oceanic waters and the pelagic larvae are transported to coastal waters by currents. The larvae metamorphose into transparent 'glass eels' and migrate into fresh water where they spend 6–20 years before the onset of maturation at which they return to the sea ('silver eel' stage). Some juveniles do not migrate into fresh water; their growth phase takes place in brackish or salt water.

Strong seasonal variation in abundance of eel was found in the Ems-Dollard. Eel appeared in the samples in April, reached its maximum catch density in July and then decreased again (Figure 8.6.21). The silver eel migration usually takes place during autumn. Most of the eels that were caught in the Dollard during the summer months resembled the silver eel stage and are most likely a pre-stage of silver eel (called 'blinker').

The catch rates of eel in the Dutch DFS were low, 97–458 specimens caught in the whole survey area in the years 1980–1984, and only 1–49 specimens in later years. Despite the low catch rates, the abundance estimates (Figure 8.6.22) reflect the general trends in the eel population and correspond with the decline observed during the glass eel monitoring in Den Oever (Figure 8.6.23). Since the peak in 1981, eel abundance has decreased significantly, a slight recovery appeared to occur in the 1990s but since then the decline has continued. This decline is observed all along the western European coast and is not related to changes in the Wadden Sea (Lozán *et al.*, 1994; Dekker, 2004).

The catches of eel in the German DYFS time series were very low ($n < 0.01/1,000 \text{ m}^2$) and occasional but occurred in all sub-regions. This is a continuation of the decline from the 1950s to the late 1980s shown by Tiews (1990).

Three-spined stickleback and river lamprey
 Strong seasonal trends in abundance were found in the Ems-Dollard for three-spined stickleback (*Gasterosteus aculeatus*) and river lamprey (*Lampetra fluviatilis*). The three-spined stickleback spends the winter in the sea and starts its spawning migration to fresh water in early spring. If this spawning migration is blocked, for example by sluices or pumping-stations, accumulation outside these fresh-water discharge locations is commonly observed (Wintemans and Jager, 2001, 2002, 2003). Highest numbers of stickleback were caught in February–March, followed by a strong decrease over the summer months, increasing again from October onwards when they return to sea (Figure 8.6.24).

The river lampreys that were caught in the Ems-Dollard were mature adults with a length of >30 cm. The spawning migration starts in autumn. Thus, catches increased from July to reach maximum numbers in October–November (Figure 8.6.25). More river lampreys were caught at the Oterdum location than in the Dollard (Kleef and Jager, 2002). Reproduction of river lampreys was observed far inland in the small river Drentse Aa during spring 2000 (de Vroome, 2001, pers. comm.). It is presumed that river lampreys from the Ems-Dollard enter Dutch inland waters through the shiplock at Delfzijl (Wanningen, pers. comm.) and swim all the way to the Drentse Aa.

River lamprey regularly occurs in the Meldorf Bight but show strongly fluctuating numbers from year to year (Figure 8.6.26). No river lampreys were caught in 1996.

8.6.4.4 Brown shrimps

Although the brown shrimp (*Crangon crangon*) is a crustacean it is included in this chapter for a number of reasons. Firstly, because brown shrimp is an important prey species for fish and birds. Secondly, a large proportion of the fishery in the Wadden Sea targets brown shrimp. Finally, the Dutch DFS and the German DYFS provide long-term series on the abundance of brown shrimp.

In the Dutch Wadden Sea, the abundance of brown shrimp fluctuates strongly from year to year. There seems to be a slight decrease from 1980 onwards in the DFS time-series, but this decrease is not statistically significant (Figure 8.6.27).

The German DYFS time series for Schleswig-Holstein over the period 1974 – 2002, also shows high fluctuations in shrimp abundance. Here, however, a significant negative trend exists (Figure 8.6.28). It is not clear, though, whether this trend really reflects a decline of stocks. It may rather be an effect of slight changes in the survey, due to larger vessels being used since 1984, operating in slightly deeper water and more outside the island chain (Neudecker, 2001). Alternatively, a shift of the shrimp stocks to deeper waters such as observed for plaice may be a natural cause. The latter possibility, also reported by fishermen, needs still to be proven with scientific data. On the other hand, no trend is visible in the landings by the German shrimping fleet (Figure 8.5.30) which indicate a highly variable though stable stock of brown shrimp in the Schleswig-Holstein area.

8.6.5 Discussion and conclusions

The catchability of a species is related to the sampling gear used. The beam trawl is the most efficient sampling gear for flatfish and other demer-

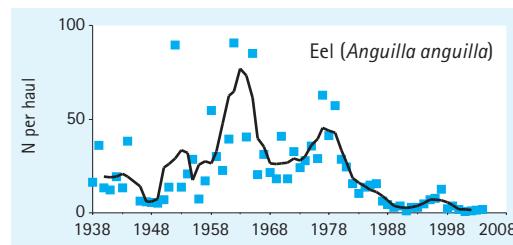


Figure 8.6.23:
Catch rates of glass eel (*Anguilla anguilla*) migrating into fresh water at Den Oever (western Dutch Wadden Sea) in April (unpublished data W. Dekker; ICES, 2004b).

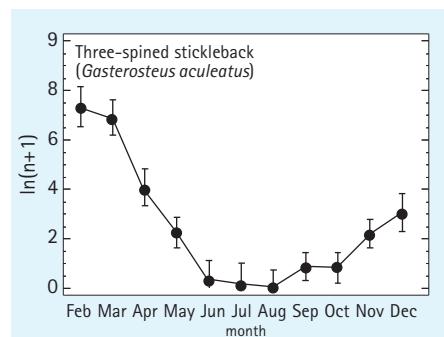


Figure 8.6.24:
Catch of three-spined stickleback (*Gasterosteus aculeatus*) (ln of the number standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

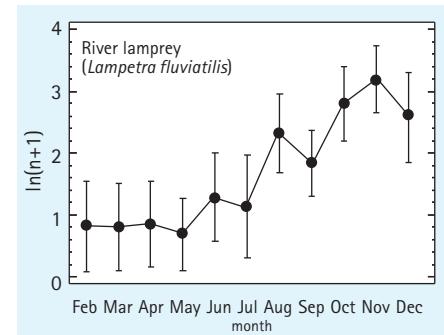


Figure 8.6.25:
Catch of river lamprey (*Lampetra fluviatilis*) (ln of the numbers standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

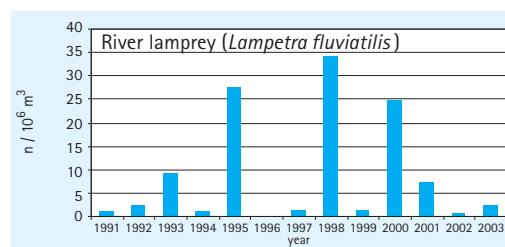


Figure 8.6.26:
Abundance of river lamprey (*Lampetra fluviatilis*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

Figure 8.6.27:
Catch rates of brown shrimp (*Crangon crangon*) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).

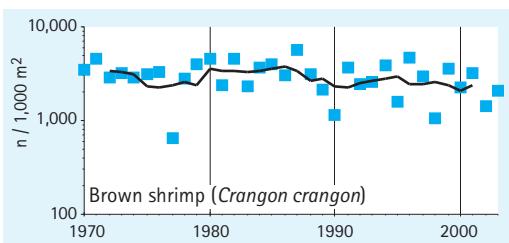


Figure 8.6.28:
Catch rates of brown shrimp (*Crangon crangon*) (autumns) in the Schleswig-Holstein region for 1974 to 2002 (DYFS data).

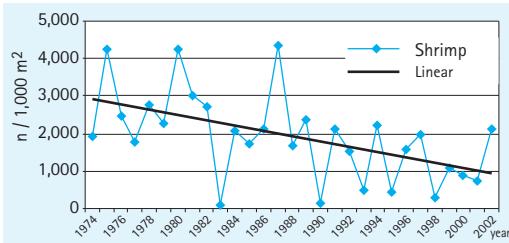
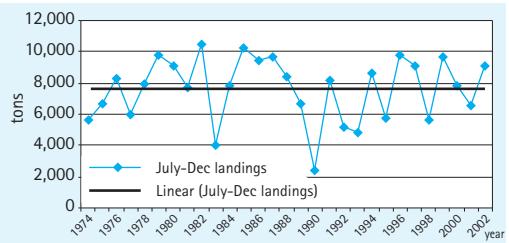


Figure 8.6.29:
Semi-annual landings of brown shrimp (*Crangon crangon*) (July to December) in Germany for 1974 to 2002.



sal species, but does not provide reliable quantitative data on pelagic species as that obtained with a stow net. Mesh size will largely determine whether or not small species and specimens are represented in the catches.

Besides gear, other factors can influence catch rates. Seasonal fluctuations must be known in order to properly interpret data from annual surveys. For example, catch rates of anchovy are generally higher in June than in August, stickleback sampling in the estuary should be carried out in first few months of the year, whereas 0-group flatfish should be monitored from summer to autumn. In addition, the area covered by a survey is important information when interpreting the data. Although the Demersal Fish Survey (Netherlands) and the Demersal Young Fish Survey (Germany) combined cover a large part of the Wadden Sea, these surveys of demersal fish are largely restricted to the tidal channels and gullies and are therefore mostly limited to habitats with medium to fine sandy sediments. The migratory fish surveys in the Ems-Dollard and in the Meldorf Bight both cover relatively small parts of the Wadden Sea. Moreover, the Dutch migratory fish survey is not a routine monitoring and was only carried out dur-

ing three years. Thus, survey results are of local validity and can differ between areas, e.g. twaite shad showing a stable population with an increasing trend in the Meldorf Bight and Elbe estuary, but an unstable situation in the Ems-Dollard.

When assessing the status of fish populations, and the changes in them, different geographic scales need to be considered. For example, in the Meldorf Bight small-scale differences (i.e. between stations) were found in the composition of functional groups (Vorberg, 2001). On a larger scale, when comparing fish fauna in Meldorf Bight and Hörnum Tief, differences in species diversity were found related to local habitat structure (e.g. hard substrate, sublittoral mussel beds) (Vorberg, unpubl. data).

The small changes in survey design during the execution of the DYFS are believed not to have severely influenced the abundance indices of fish. A more detailed analysis still needs to be made, especially for species with a seasonal pattern. This may be important for shrimp, where the timing of the survey is considered not optimal in view of the spring migration towards the shallower parts of the Wadden Sea (Siegel, 2003, pers. comm.). The effect of variability of environmental conditions on catch data is partly known but not well enough documented, e.g. the effect of weather, light intensity, turbidity, depths, sediment composition, tidal currents (Bolle *et al.*, 2001; Neudecker *et al.*, 1998) and might change results to some extent. However, strong year classes in fish or shrimp as well as clear trends will remain evident. Weak trends, however, could be the result of some bias due to underestimating the effects of environmental or seasonal factors. Conclusions have therefore to be drawn with great care and more research in this respect is necessary.

For this report we have collated all data available, but given the limitations within as well as between the surveys, this data cannot provide a comprehensive assessment of the status of fish in the Wadden Sea. Nevertheless, some important trends can be shown:

Herring, Sprat and Anchovy
Catch results for herring in the Meldorf Bight are in agreement with the development of the North Sea herring. After the population breakdown at the end of the 1970s and again in the mid 1990s, a successful fishery management and good reproduction has led to a stable and high standing stock. Sprat, on the other hand, shows a decreasing trend in the Meldorf Bight. This corresponds to North Sea data indicating low population size and recruitment success in the late 1990s (Zimmermann,

1998). A positive trend could be assessed for anchovy (Vorberg, 2003). The development of this species in the Wadden Sea area of Schleswig-Holstein is regarded a result of increased temperatures.

Twaite shad

Twaite shad is listed in Annex II of the Habitats Directive and classified as vulnerable in the red list of marine fishes of the Wadden Sea (Nordheim *et al.*, 1996). High numbers and an increasing trend of twaite shad observed in the Meldorf Bight indicate a stable population, which uses the Elbe estuary for spawning. This would be in line with the improved stock in the German Bight (Stelzenmüller *et al.*, 2004). In the Ems-Dollard estuary the presence of adult and juvenile twaite shad might indicates a local spawning population. Low numbers of 0-group twaite shad in 1999 only, suggests that the population is not stable. Another possibility might be that the 0-group twaite shad in the Ems estuary originate from, for example, the Elbe, where a fairly substantial spawning population exists (Thiel *et al.*, 1996).

Smelt

High densities of smelt occur in the Elbe River, especially in the lower reaches. An increasing consumer demand has led to an intensive fishery for the migrating fish. Since the end of the 1990s about 20-30 tons have been caught per year and the landings in 2003 even reached a new record of 45 tons.

Smelt is sensitive to low oxygen levels and may therefore be used as an indicator of water quality. In the Thames estuary, the smelt completely disappeared when water quality was poor due to the discharge of raw sewage. Smelt stocks managed to recover as water quality improved. Because the smelt is a good indicator of estuarine water systems, the recording of trend data of smelt population abundance is necessary. At present, such data is lacking.

River lamprey

The river lamprey is listed in Annex II of the Habitats Directive (Kloppmann *et al.*, 2003) and is classified as vulnerable in the red list of Wadden Sea fishes (Nordheim *et al.*, 1996). Hubold and Ehrich (2001) reported that river lampreys occur regularly in the German Bight since 1990 as well as in rivers flowing to the North Sea. Since 1998, fishermen in the Ems and Weser rivers found increasing numbers of river lampreys in their catches. Several hundreds of kilograms were thrown overboard due to the by-law on coastal fishery for Niedersachsen (Hagena, 2000).

Flatfish

The numbers of juvenile flatfish using the Wadden Sea as a nursery are clearly declining. The abundance of dab and 1-group plaice in particular has strongly decreased. The decline in flatfish in DFS catches is very prominent and has resulted in a decrease of the total catch weight. The lower catch rates in the Wadden Sea are mainly caused by an offshore shift in the distribution of juvenile flatfish, which, however, is unlikely to be related to local environmental changes within the Wadden Sea. The causal factors underlying this shift in distribution are not yet fully understood and certainly need further investigation.

Resident species

Five-bearded rockling and hooknose, classified as (near) resident species, do not show any clear trends in abundance over longer time periods, whereas the abundance estimates of the true resident species bull rout and eelpout seem to fluctuate on a decadal scale. Current catch rates are significantly lower than in the early 1980s, but not as a result of a continuous decline. It is plausible that the trends in abundance of bull rout and eelpout are related to the availability of suitable habitats, such as mussel beds, but no conclusive evidence has yet been presented to confirm this hypothesis. The possible effect of habitat change due to the development of Pacific oysters in the Wadden Sea has not been investigated at all.

Other species

In this QSR data for only twenty fish species of major importance is presented. It should be noted that the remaining species known from the area (cf. Witte and Zijlstra 1978; Vorberg and Breckling, 1999) may undergo changes of which we are not aware. The recently found increasing occurrence of reticulated dragonet (*Callionymus reticulatus*) in the German part of the Wadden Sea may serve as an example (Neudecker and Damm, 2004).

Brown shrimp

In certain years, brown shrimp suffered extreme predation by whiting. In more recent times, however brown shrimp have benefited from the extremely low stocks of cod and whiting and resulting low predation levels. Brown shrimp stocks seem to be in no way biologically endangered. According to present knowledge they may only suffer from short term natural changes or be subject to high exploitation rates which are generally compensated by new year-classes coming in following especially cold winters (Neudecker *et al.*, in prep.).

Regional shifts of the brown shrimp stocks are commonly known from fisheries and are partly reflected in the fluctuations of Dutch and German annual landings. A continuous decrease in the abundance and landings of brown shrimp on the French and Belgian coast (ICES, 2003; Tetard, pers. comm.) and a synchronous increase in the German-Danish region might indicate a biological response to climatic changes. This is a hypothesis which is not yet being investigated.

8.5.6 Recommendations

At present there is trend monitoring for demersal fish in the Dutch and German Wadden Sea (DFS and DYFS, respectively). Pelagic fish are being monitored only on a regional scale in the Schleswig-Holstein part of the German Wadden Sea. The Danish Wadden Sea is not covered by any such program. Therefore, the development of a trilateral monitoring program, based on trilateral targets to be developed, is recommended, which should take into account the following:

- The formulation of trilateral targets concerning fish is indispensable for structuring and focusing monitoring, and relevant concomitant research, of this important group of inhabitants of the Wadden Sea.
- A comprehensive monitoring of the Wadden Sea requires expansion of the spatial cover-

age of the demersal fish surveys in, for example, the Danish Wadden Sea and Weser - Jade region).

- The value of the current national monitoring programs can be increased by trilateral 'tuning' and harmonization of methods, gear and sampling sites and sampling times.
- More information should be collected on pelagic species (herring, smelt) and diadromous species. For the estuaries good data on smelt is required to be able to judge the state of these water systems.
- For pelagic fish monitoring a network of sampling sites has to be installed considering the spatial differences in the distribution of fish species in the trilateral Wadden Sea.
- For species showing a very strong seasonal pattern of abundance the present monitoring periods must be adapted.
- The functional relationship between fish species and habitats, e.g. the (sub)tidal mussel beds, eelgrass and reed beds should be investigated.
- For a better understanding of changes in the fish community, more knowledge of the (Wadden Sea specific) autecology of non-commercial species is required.

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9. Beaches and Dunes

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9.1 Beaches

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



9.1.1 Introduction

At the Stade Conference in 1997 the Trilateral Wadden Sea Plan was adopted with common Targets for habitats and 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 As-

essment 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'.

Activities aimed at coastal protection, such as beach and nearshore nourishment and the build-

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.

ing 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 Target evaluation

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
<u>Xerosere:</u>			
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 land-

TMAP-type: Hygrosere:	Dune slack types	Vegetation	Natura 2000 habitat types
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	Cicdietetum 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.	

scapes, successional stages and species, especially changes in the distribution of rare plants, indicative 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 responsible for present ecological trends, such as coastal protection, air pollution, groundwater extraction and nature conservation and management, will be briefly evaluated. The chapter will 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 typology. For the first time it is possible to create an

Table 9.2.1 (cont.)

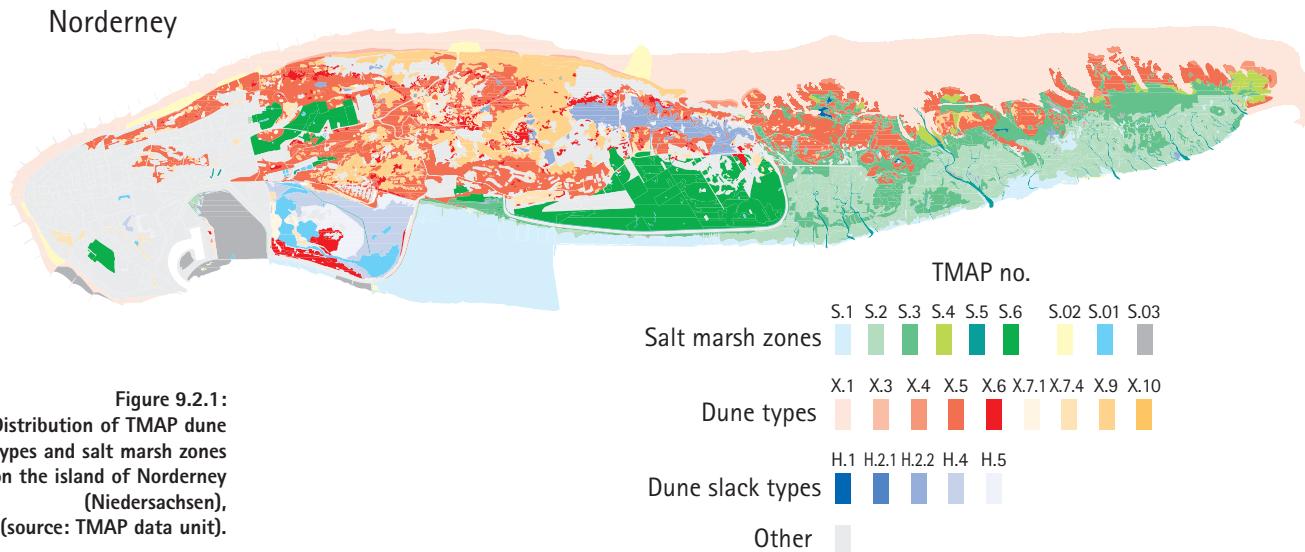


Figure 9.2.1:
Distribution of TMAP dune types and salt marsh zones on the island of Norderney (Niedersachsen), (source: TMAP data unit).

overall picture of the status of the dune ecosystems in the Wadden Sea area. An example is given in Figure 9.2.1.

The typology consists of two major sections, *viz.* the Xerosere (generally: dry dune vegetation

types) and the Hygrosere (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.

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	(%)	(ha)
Natura 2002-type:	2110	2120	2130	2140	2160	2170	2180	2190	2190	2190	2190	2190	2190	2190	2190	2190	2190	2190		
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	
Wangerode	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	

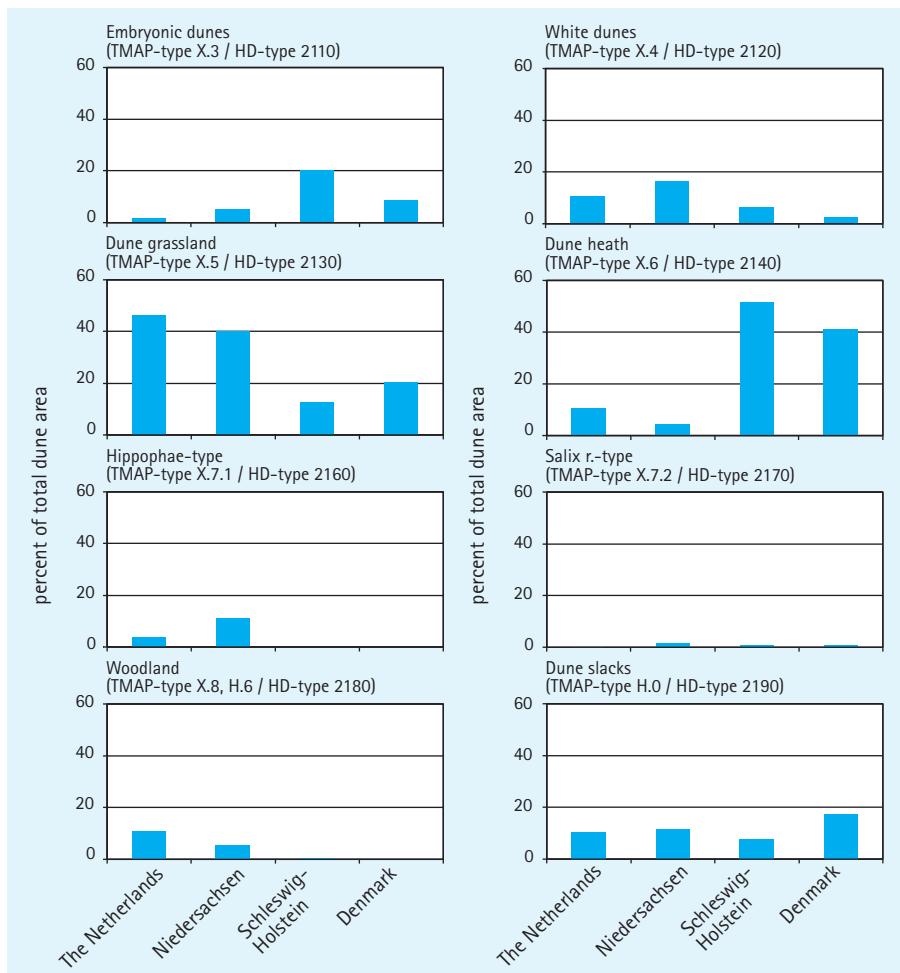


Figure 9.2.2:
Relative area (%) of dune types and total area (ha) per country/state.

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 9.2.2.

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 Rottumerplaat, and Griend (between Harlingen and Terschelling), no detailed vegetation data was



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

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.

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 calculation 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 albifrons*), 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 disease 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.

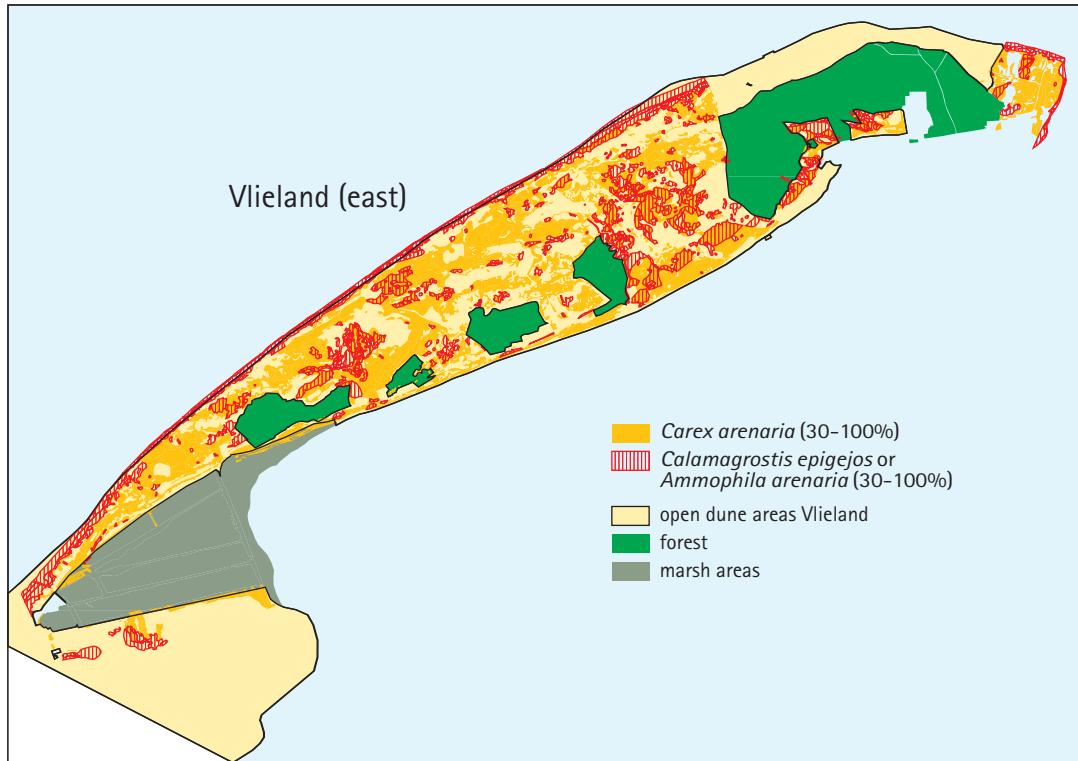
Other qualifying species of the Birds Directive are faced with sharp declines as well, e.g. wheatear and red-backed shrike. Recent research showed clear relationships between the occurrence of red-backed shrikes and decreased availability of prey, which in optimal conditions comprises a large variety 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

Figure 9.2.3:
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.



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 equilibrium 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 systems 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 9.2.3) 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 9.2.4). 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.

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

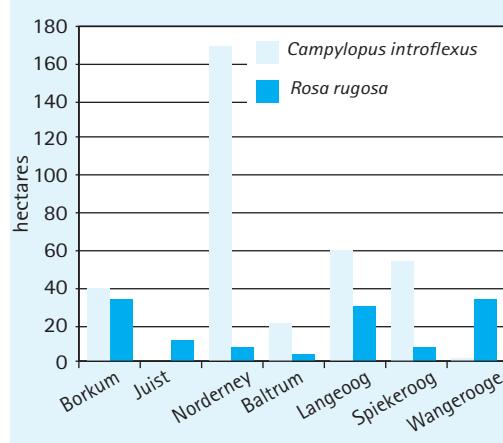


Figure 9.2.4: Occurrence (ha) of neophytes on the islands of Niedersachsen (Hahn, 2005).

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 coast-

line 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).

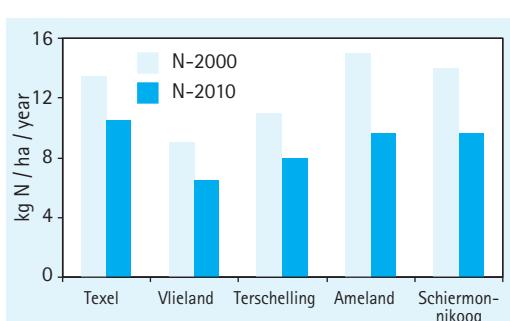
On the mainland the deposition of nitrogen has considerably increased during the last century but declined again since beginning of the 1990s. The Netherlands Environmental Assessment Agency (RIVM, 2004) gives the following average figures for The Netherlands: total N-deposition (wet and dry) rose from 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 9.2.5.

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

Figure 9.2.5:
Nitrogen deposition on the
Wadden Sea islands in
2000 and 2010 (from
Buijsman, 2003).



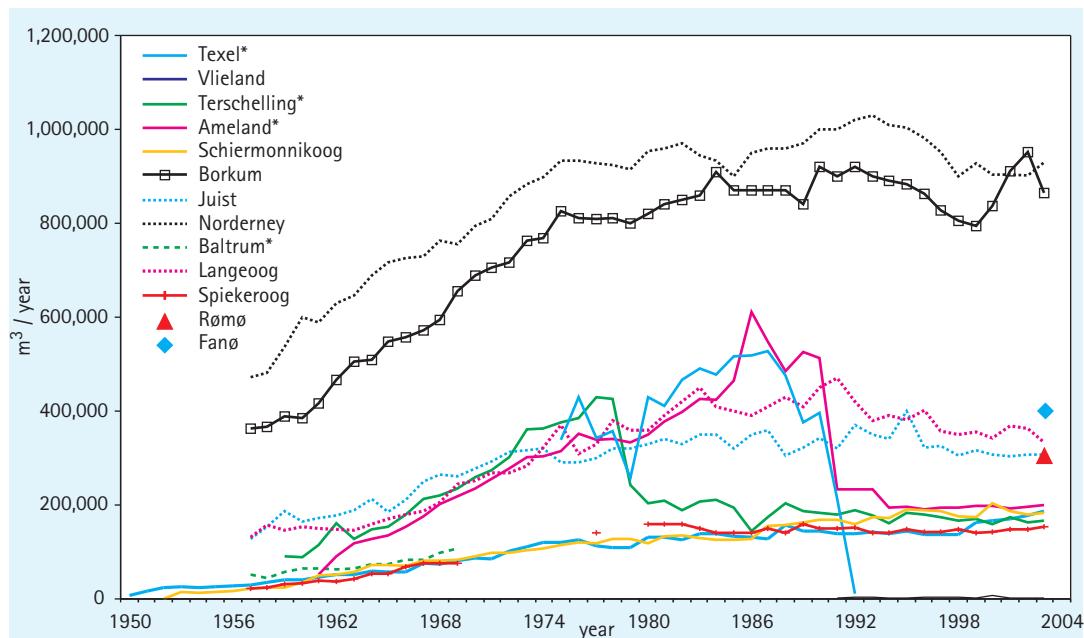


Figure 9.2.6:
Groundwater extractions
on the Wadden Sea islands
(in m³/year); asterisks
indicate islands which now
are totally or partly
provided with drinking
water from the mainland.

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 9.2.6 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 values 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 were 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 m³/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 m³/year) and Juist (about 300,000 m³/year) and a relatively small extraction on Spiekeroog (about 150,000 m³/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; Pe-

tersen and Süterling, 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 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. 9.2.6). 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 m³) and Fanø (302,000 m³), 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

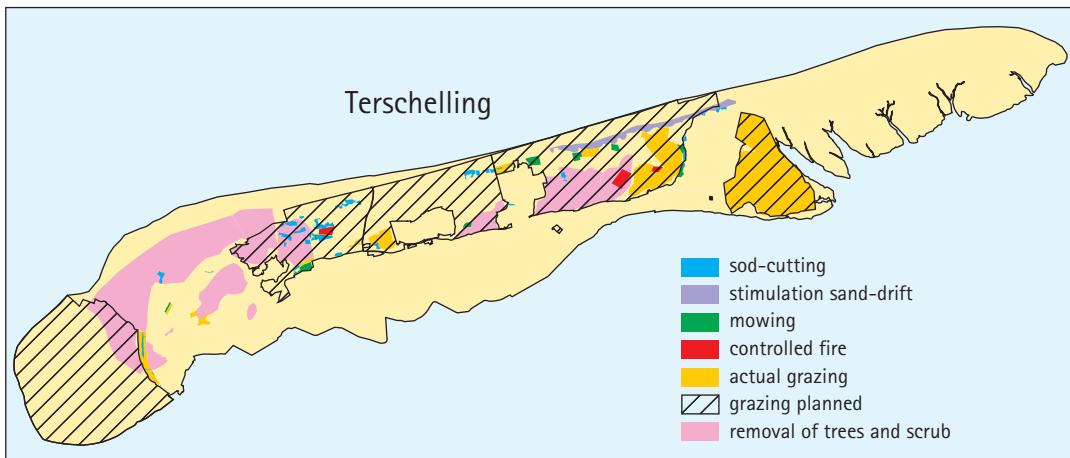


Figure 9.2.7:

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.

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 ecosystems (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 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 suc-

cessful 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 9.2.7 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-fo-

cused 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 Target evaluation

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-inhabited '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.

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.

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 two thirds 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 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.



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

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 on page 254 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 ground-water 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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10. Estuaries



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The river mouth of the Varde Å, Denmark (Photo: J. Frikke).

10.1 Introduction

Estuaries can be defined as tide influenced transition zones between marine and riverine environments. According to the Wadden Sea Plan, the estuaries in the Wadden Sea Area are delimited on the landward side by the mean brackish water limit (salinity 0.5) and on the seaward side by the average salinity of 10 at high water in the winter situation. As in the 1999 QSR the freshwater tidal reaches were included in this review, as they form an integral part of the estuarine habitat. The EC-Water Framework Directive (WFD, 2000, Art. 2) also gives a broader definition of estuarine transition zones: 'Transitional waters are bodies of surface water in the vicinity of river mouths which are partly saline in character as result of their proximity to coastal waters but which are substantially influenced by freshwater flows'.

Target

Valuable parts of estuaries will be protected and the riverbanks will remain and, as far as possible, be restored in their natural state.

In the Wadden Sea, six estuaries can be described: Varde Å, Godel, Eider, Elbe, Weser and Ems; in the Dutch Wadden Sea, no tidal rivers have remained (Schuchardt *et al.*, 1999). The main features of these estuaries are shown in Table 10.1.

The Godel is in fact a small river on the island Föhr. It is mentioned as an example for other smaller rivers within the coastal area along the Wadden Sea.

In the next paragraphs new information on the main developments in these estuaries, not documented in the 1999 QSR, will be presented.

10.2 Results of the 1999 QSR

There are only six estuaries in the Wadden Sea area (Ems, Weser, Elbe, Eider, Godel, Varde Å) so that there are only few larger natural transitions between fresh and salt water. The Varde Å and Godel estuaries have retained their natural character. The Ems, Weser and Elbe and their tributaries have been modified considerably by endikement and deepening. The anthropogenic impact on these estuaries is still increasing as a result of the current deepening of the Elbe and Weser and the construction of a storm surge barrier in the Ems. The 1999 QSR concluded that these estuaries are moving farther away from the Targets.

It was recommended to further detail the Target for estuaries taking into account the special character of each estuary and specifying the notion 'valuable parts', to evaluate the consequences of further anthropogenic impacts, to prepare an inventory of the most suitable sites for de-embankment and to improve the physical condition, such as restoration of gradients of salinity and tidal amplitude.

	Varde Å	Eider	Elbe	Weser	Ems
Drainage area above tidal weir ($\times 10^3 \text{ km}^2$)	1.1	2	135	38	13
Mean river discharge (m^3/s)	13	23	725	323	125
Mean tidal range at tidal weir (m)	1.3	2	2.4	4.1	2.8

Table 10.1:
Main features of the five larger estuaries debouching into the Wadden Sea (Schuchardt *et al.*, 1999).

10.3 Hydrological and morphological changes

Since the beginning of the 20th century, the Elbe, Weser and Ems estuaries have been significantly altered due to deepening of shipping routes and coastal protection measures (Schuchardt *et al.*, 1999; Lozán and Kausch 1996). An analysis carried out within the Water Framework Directive in 2004, resulted in a classification of these transitional waters as 'Heavily Modified Water Bodies' because of significant changes of such aspects as width-depth ration, tidal amplitude, upper tidal limit, current velocity and of a reduction of tidal flats and brackish marsh habitats (EG-WWRL Bericht Ems, 2004; EG-WWRL Bericht Tideweser, 2005; EG-WWRL Bericht Tideelbe, 2004; EG-WWRL Bericht Eider, 2004).

10.3.1 Hydrological changes

Jensen *et al.* (2003) investigated the changes in mean high water (MHW) and mean low water (MLW) time series of the Ems, Weser and Elbe over the period 1936 to 1999. There has been a rise in MHW over time, which corresponds to the sea level rise in the North Sea and therefore has a natural cause. However, their results on MLW show a decreasing trend over time which deviates from results seen in the North Sea. The authors attribute this to the effects of enlargement measures in the rivers. A more detailed description is given below for each of the three estuaries.

The differences of the MHW of the gauges Herbrum and Papenburg in the Ems do not show any significant changes. A slight rise of the MHW differences can be listed from the year 1964. Within the time span 1964–1997 some greater enlargement measures in the Lower Ems increasing the depth to 5.7 m (in 1984), to 6.8 m (1991/92) and to 7.3 m (in 1994) were carried out. The MLW differences of the gauges Herbrum and Papenburg decreased at the gauge Papenburg (approx. 34 cm) and at the gauge Herbrum (approx. 66 cm) between the years 1958 and 1962. The causes for that are attributed to the enlargement measures in 1984, 1991/92 and 1994.

The MHW differences of the gauges Bremen-Große Weserbrücke and Vegesack in the Weser show an increasing trend, the MLW differences a decreasing trend. In this time series, the greater enlargement measures can be seen (1921/28 enlargement of the outer Weser to approx. 10 m, 1969/71 enlargement of the outer Weser to approx. 12 m, 1973/78 enlargement of the lower Weser to approx. 9 m). A further enlargement of the Weser estuary is still at the planning stage (www.weseranpassung.de).

The MHW differences at the gauge St. Pauli (and with that the MHW in Hamburg) in the Elbe did not change significantly from about 1950 up to about 1964. In this period the shipping fairway was deepened to 11 m. From about 1964 up to 1978 (fairway enlargement to 12 m and then to 13.5 m) the MHW differences increased about 22 cm. After the end of the enlargement measure, the MHW differences did not change significantly up to 1999. The MLW differences at the gauge St. Pauli decreased uniformly from around 1960 (11 m enlargement) up to about 1974 (beginning of the 13.5 m-enlargement). After that an accelerated decrease occurred up to the end of the enlargement measure in 1978. During the 13.5 m-enlargement measure a lowering of MLW of 23 cm occurred, followed by a further lowering around about 24 cm up to 1999. This can be taken as a long-term hydrological effect. The differences between MHW and MLW at the gauge Bunthaus show a similar behavior as the differences at the gauge St. Pauli. The consequences of the enlargement measures are reflected in the time series. It is striking that the run of the differences at the gauge St. Pauli is more regular than at the gauge Bunthaus. The cause for this behavior is the higher river discharge influence and the lower influence of the tide at Bunthaus as compared to St. Pauli. A further enlargement of the Elbe estuary is still at the planning stage (www.zukunftelbe.de).

It has to be noted, that at present for the estuaries Ems and Elbe the differences between MLW in the estuary and MLW in the North Sea are nearly zero, whereas for the Weser estuary this difference has been zero since 1980. Further investigations are needed to clarify this.

In the Varde Å estuary there have not been major changes in the hydrological regime since many years.

10.3.2 Morphological changes

Since the 1999 QSR deepening of shipping routes has continued in the Elbe and Weser estuaries and further plans are being discussed for future enlargement measures. In the Ems, the construction of the storm surge barrier (Emssperrwerk) at Gandersum was started in 1998 and completed in 2002. The storm surge barrier is designed as a flood defense and to artificially maintain high water depth to allow passage of large cruise ships built at the Meyer shipyard at Papenburg. When the barrier is open, the profile of the river is unchanged, so there are no consequences for the geomorphology. Dutch-German measuring campaigns have not been able to demonstrate clear ecological effects due to closure of the barrier .

The siltation of the Bocht van Watum (Ems) has continued since 1999 (CSO, 2001). The gully might disappear in time, changing the system from a 2-gully system to a 1-gully system. There are no management objectives yet for this process in the Ems, as opposed to the Western Schelde estuary where the 2-gully system is preferred from the point of view of safety, shipping and ecology.

Between 1970 and 2000 there was an increase in the concentration of suspended matter in the middle of the southern part of the Ems estuary close to Delfzijl (Merckelbach and Eysink, 2001). It is unknown if this is caused by the dredging activities. The 1999 QSR reports a yearly average of 9.4 million m³ of sediment dredged from harbors and shipping channels in the Ems estuary over 1989–1997. As Dutch dredging did not change much (about 4 million m³/yr; data Rijkswaterstaat) and German dredging in 2002 amounted to about 7 million m³ (Mulder, 2004), present dredging effort is estimated at 9–10 million m³ annually. Although some of this sediment was actually removed from the system, the majority was dumped elsewhere in the estuary. There is continual dredging, primarily for maintenance purposes. The effects of this on the estuarine system with regard to coastal protection and ecology are unclear. Local effects have been studied (BfG, 2001). In the 'Emder Fahrwasser' continuous dredging takes place. The material (1/3 sand, 2/3 mud) is relocated at disposal sites in the outer estuary ('Dukegat'). The described effects include local and short-term raised turbidity, and incorporation of mud in originally sandy sediments. Regarding biota there is partly reduced biomass or species numbers and a shift in species composition, the latter being caused by changes in sediment composition. In the upper Ems estuary (upstream of Gandersum) dredging is carried out only for maintenance purposes on a case-by-case basis for single cruise ship transfers. The dredged material is disposed on land.

10.4 Ecological structure

A characterization of estuarine habitats, abiotic structures and flora and fauna was given by Schuchardt *et al.* (1999). Recent information on the importance of estuaries for fish is compiled in chapter 8.6 by addressing diadromous fish (pelagic and demersal); for the Ems-Dollard estuary, results of a migratory fish survey are presented.

The WFD Reports 2005 have also pointed out that the Ems, Weser and Eider estuaries are still influenced by high loads of nutrients and con-

taminants mainly from diffuse sources upstream.

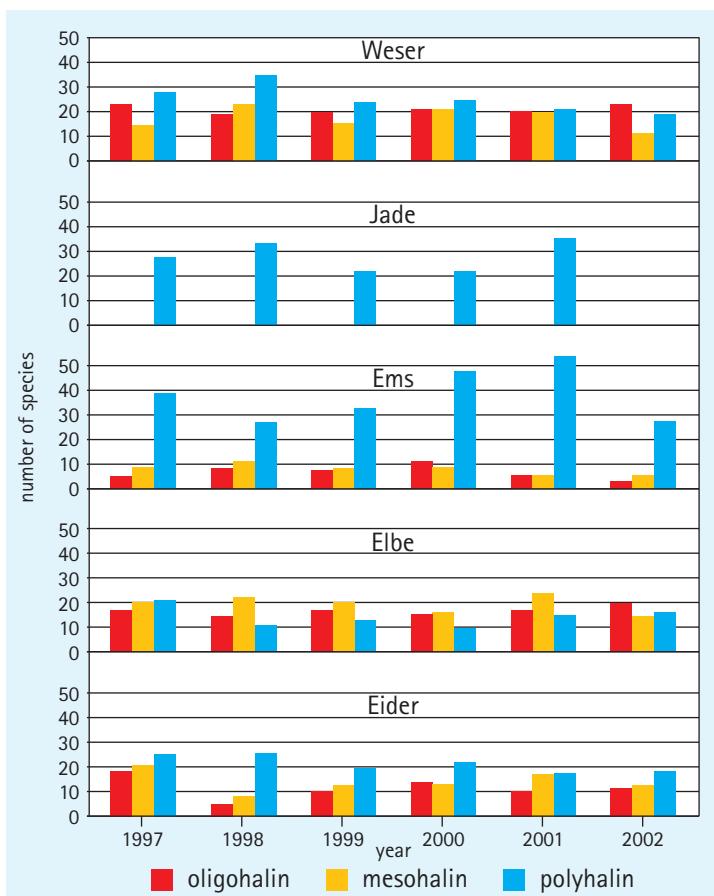
Macrozoobenthos communities have been monitored for all German estuaries by the Federal Institute of Hydrology (BfG, Koblenz) since 1995, and is used as an indicator for the evaluation of environmental conditions. Samples are usually collected once a year in the fall season. In the Ems, Weser and Elbe estuaries six stations are monitored, while in the Jade embayment five stations are investigated, as are three stations in the Eider estuary. At each station six replicates were usually collected using a van-Veen grab (0.1 m²) and a dredge haul was taken (Nehring and Leuchs, 1999).

In Figure 10.1 numbers of macrobenthos species are presented for different estuaries and their salinity zones for the years 1999–2002. Within each of the German estuaries, with the exception of the Elbe, there is a trend of higher species numbers being present in the polyhaline part (more seaward), and lower numbers in the oligohaline part (towards the river). In the Elbe estuary, lower species numbers were found in the polyhaline part which could be explained by higher contamination of sediments. The low species numbers in the oligo- and mesohaline parts of the Ems are probably due to occurrence of fluid mud. The species numbers in the Eider estuary are not fully comparable to those of other estuaries due to a lower number of samples.

Among the macrobenthos, also Red List species were found in these estuaries, *viz.* the hydroid *Sertularia cupressina*, the anemones *Metridium senile* and *Urticina felina*, the polychaetes *Ophelia rathkei*, *Boccardiella ligerica* and *Nereimyra punctata*, the crustaceans *Corophium lacustre*, *Eurydice pulchra*, *Idotea linearis* and *Palaemon longirostris*, the bivalve *Petricola pholadiformis*, and the gastropod *Crepidula fornicata*. The occurrence of these species indicates the presence of suitable biotopes, although no information is available about the spatial extent of these.

In the Varde Å estuary, several decades of intensive fertilization and drainage of salt marshes and meadows did cause habitat loss and impoverishment of biodiversity. In 1998, a restoration project was started which aimed at less intensive agriculture, resulting in a reduction of nutrient and pesticide leaching into the aquatic environment and an improvement of the biological values of the meadows and wetlands in the estuary. The aim of this project is mediated by compensation to the land owners and users of any loss of income. The expected result is a better compliance to the restoration obligations in the Birds and Habitats Directives.

Figure 10.1:
Development of macrozoobenthos species numbers (1997–2002) in the estuaries of the rivers Eider, Elbe, Ems and Weser and in the Jade embayment at three stations (source: BfG, Koblenz).



10.5 Target evaluation

Although the target is not specific as to the 'valuable parts' of estuaries to be protected and restored, the available information shows that most estuaries of the Wadden Sea still do not meet the target, mainly as a result of significant changes in hydrology, geomorphology and of poor water quality.

10.6 Conclusions

The Ems, Weser and Elbe estuaries and their tributaries have been modified considerably by endicement, deepening, harbor construction and other human use which resulted in significant changes in width-depth ratio, tidal amplitude, upper tidal limit, current velocity and in a reduction of tidal flats and brackish marsh habitats.

In the first analysis and characterization of transitional waters within the WFD Reports 2005 (WFD, Article 5) all transitional waters were classified as 'Heavily Modified Water Bodies' because of significant morphological changes and corresponding negative effects on biological components. It was also concluded that the 'Good Ecological Potential' of these waters will probably not

be reached by 2015 mainly due to the still high input of nutrients and hazardous substances. Although the loads have decreased over recent decades (see chapter 4) a negative effect on the estuaries' ecosystem is assumed. Further measures are necessary to reduce these significant loads.

The lower number of macrozoobenthos species in the Elbe estuary as compared to the Weser and Ems estuary is probably caused by a higher degree of pollution. However, several new species (neozoons) were found in the German estuaries for the first time indicating ecological space within the estuarine benthos communities. Occurrence of 'Red List' species was also observed which may indicate the presence of suitable biotopes; further information is necessary concerning the spatial extent of these biotopes.

In the Varde Å estuary, a project is ongoing since 1998 aimed at restoration of natural values of estuarine habitats through reduction of agricultural practice in salt marshes and meadows.

10.7 Recommendations

A number of recommendations from the 1999 QSR are still valid. In addition, the WFD Reports 2005

have to be taken into account. The following recommendations pertain to the Wadden Sea estuaries:

- Integration of the tidal freshwater reaches into the definition for estuaries according to the typology of the Water Framework Directive.
- Existing ecological targets for estuaries must be specified, taking into account the individuality of each estuary.
- Monitoring of ecological long-term changes, other than water quality and macrozoobenthos in the estuaries, is necessary.

- Active restoration of estuarine habitats (especially shallow areas and foreland) is necessary in all estuaries under consideration. Problems linked to the artificial increase of the tidal range have to be given special attention.
- Consequences of further deepening, barriers and harbor extension should be evaluated very carefully, taking into account the historical deterioration of the estuaries.
- Further improvement of water quality is necessary, especially for the Elbe.

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11. Offshore Area

Karsten Laursen
Karel Essink



The red-throated diver (*Gavia stellata*) is the most common diver in the Offshore Area (Photo: K. Günther).

11.1 Introduction

The Offshore Area of the Trilateral Cooperation Area (Wadden Sea Area) is defined as the near-shore zone between the barrier islands and the line 3 sea miles from the baseline, respectively up to 12 sm in case the conservation areas exceeds the 3-sea-mile line (see also Figure 11.1). The area covers about 4,000 km², and is dominated by water depths of more than 10 m. A close connection between the intertidal areas inside the Wadden Sea and the Offshore Area justifies its inclusion in the Cooperation Area. This connection is clear with respect to water, geomorphology and biology. The tide causes a daily exchange of water between the Wadden Sea and the North Sea, the extent of which is modified by wind conditions. The Offshore Area forms one coherent geomorphological system with the Tidal Area, which can be demonstrated by sand transport. Several fish species spawn in the Wadden Sea; as young fish they move to the Offshore Area to grow up. Birds and sea mammals demonstrate both a daily and a seasonal shift in their use of the Tidal Area and the Offshore Area. These few examples illustrate the close connection between the two parts of cooperation area. The following Targets apply:

Targets

- An increased natural morphology, including the outer deltas between the islands.
- A favorable food availability for birds.
- Viable stocks and a natural reproduction capacity of the common seal, grey seal and harbour porpoise.

11.2 Water and geomorphology

Tides are the driving force for a daily exchange of water between the Wadden Sea and the North Sea. The offshore zone up to a depth of about 20 m forms a coherent geomorphological unit with the Tidal Area. Through the tidal inlets in between the barrier islands, sand and silt are transported back and forth between the Tidal and Offshore Areas ('sand sharing system'). The consequence of this dynamic equilibrium is that disturbances will be compensated until a new equilibrium is reached. Sea level rise and bottom subsidence cause a deepening of the tidal basin resulting in an increased net sand import from the offshore zone. Ultimately this sand originates from the seaward shores of the islands. Together with a net sedimentation along the mainland shore, this results in a landward movement of the islands (de Jong *et al.*, 1999).

Extraction of sand and gravel is generally carried out in the North Sea outside the 20 m depth contour. This material is used for construction works on the mainland and for replenishment (or nourishment) of eroding coasts, for example, along the Wadden Sea. For aesthetic reasons, shore replenishment with sand was favored to the use of concrete and stones, as is the case in many areas such as on Sylt (Reise and Lackschewitz, 2003). The yearly extraction of sand and gravel in the southern North Sea amounts to 45 million m³ (Lozán *et al.*, 2002). Recovery of the areas where sand was extracted depends on local sediment dynamics, and is fast in areas with strong dynamics. The sand and gravel extraction results in a reduction of benthos biomass and change in species com-

position, at least temporarily. A complete recolonization of benthos after extraction takes between one month and ten years and sometimes even longer. In most cases, however, it takes a few years. The recolonization depends very much on the nature of the sediment and on water currents. The first species to invade are opportunistic taxa, and after a couple of years species from the original community begin to settle again and develop (Lozán *et al.*, 2002).

In 1995, an 800 m long stone cross-shore groyne was built near the northern tip of the island of Texel (NL), with the aim of long-term reduction of the cost of sand nourishments necessary to counteract local coastal erosion. This resulted in deposition of sediment on both sides of this groyne, forming a new beach plain. Also changes occurred in the geomorphology of the ebb tidal delta of the inlet Eijerlandse Gat, where a rearrangement of tidal channels was observed (de Kok, 2005).

11.3 Biology

The biology of the Wadden Sea and the North Sea is intimately linked. Phytoplankton is transported from the offshore zone to the Wadden Sea proper and, after dying off, is remineralized. The import of organic matter from the offshore zone is one of the main causes of the food richness of the Wadden Sea. Both cockles and blue mussels may restock the Wadden Sea from populations in deep water refuges in the North Sea after severe winters have decimated the population of the exposed tidal flats. Motile animals like fish, shrimps and crabs largely leave the Wadden Sea in autumn to survive the winter in the relatively warm waters of the North Sea, after which they return to the Wadden Sea. Without the high productivity in the Wadden Sea, the stock of these species would be greatly reduced (de Jong *et al.*, 1999).

11.3.1 Zoobenthos

In the coastal waters of the North Sea, the most important zoobenthos groups are molluscs, polychaetes, crustaceans and echinoderms. Polychaetes are the most abundant. Molluscs are second in abundance but have the highest biomass.

11.3.1.1 Zoobenthos communities

The ICES Study Group on the North Sea Benthos Project 2000 has analyzed zoobenthos samples from the North Sea taken in 2000/2001. Samples were grouped according to their similarity in species composition using PC-ORD and TWINSPAN cluster analyses. This resulted in the identification of nine clusters in the North Sea, largely re-

lated to water depths (increasing from south to north) and to differences in substratum types (coarse vs. fine) (SGNSBP, 2004).

At least two of these clusters were found along the Belgian-Dutch-German coast comprising the Offshore Area of the Wadden Sea Cooperation Area. The benthic fauna in these clusters had a relatively low species diversity, with, however, enhanced values in complex biotopes, i.e. with mixed substrate from fine to coarse sands, gravel and stones, such as near Borkum Riff and in the outer Amrum Grounds.

11.3.1.2 *Spisula*

Two species of the clam *Spisula* occur in the Offshore Area, viz. *Spisula subtruncata* and *S. solidula*.

Surveys in The Netherlands since 1995, have shown that *Spisula subtruncata* is distributed all along the North Sea coast off the Frisian Islands south to the Delta area (Craeymeersch *et al.*, 2001). *Spisula* is being monitored in the spring, including 800-1000 stations. The biomass calculated for the North Sea coast off the Wadden Sea varies from 25,000 tons fresh weight in 1996 to about 210,000 tons in 2000. Yearly variations of the same magnitude were also recorded in other areas off the Dutch North Sea coast. However, the variation did not occur synchronously. The yearly commercial landings of *Spisula subtruncata* in The Netherlands in the period 1996-2001, were between 16,000-37,000 tons. Information on the occurrence of *Spisula subtruncata* in Germany and Denmark is scarce. In Danish waters off the Wadden Sea, the species was reported for some years, but has disappeared during recent years (P. Sand Kristensen, pers. com.)

The clam *Spisula solidula* was investigated in 2000-2001 off the Schleswig-Holstein Wadden Sea (Rumohr, 2002). It occurred at Amrum bank at about 10 m depth off the islands of Sylt and Amrum, off the peninsula of Eiderstedt and at Vogelsand outside the Elbe estuary. Densities up to 30 individuals per m² were found at Amrum Bank, whereas at Vogelsand and in the area off Eiderstedt only 1-10 individuals per m² were reported. Due to its low densities, this species is not fished.

11.3.2 Birds

11.3.2.1 Coastal and marine species

Birds using the North Sea off the Wadden Sea have not been subject to regular monitoring. However, knowledge of the birdlife was derived through different initiatives and in national campaigns in the 1980s and 1990s and has grown enormously in recent years, especially in order to fulfill the obli-

Species	1% level of flyway	Period	Estimated number	Number in % of total population
Red/Black-throated diver	10,000	Dec-Mar	36,000 *	4
Eider	10,300	Oct-Feb	63,000 *	6
Common scoter	16,000	Dec-Feb	303,000 *	19
Velvet scoter	10,000	Dec-Feb	7,000	<1
Little gull	840	Mar-May	2,500 *	3
Common gull	17,000	Dec-Feb	67,000 *	4
Lesser black-backed gull	1,900	May-June	50,000 *	26
Herring gull	13,000	Nov-Feb	48,000 *	4
Sandwich tern	1,700	Apr-May	13,000 *	8
Common tern	1,900	Apr-May	4,000 *	2

Table 11.1: Estimated numbers of the most numerous seabird species occurring in the North Sea between the Wadden Sea islands and 20 m water depth in specific months of the year (Skov *et al.*, 1995; Garthe, 2003). * Number of international importance. 1% level according to Delany and Scott (2002).

gations of the EC Birds Directive. For example, Germany has recently concluded a project on numbers and distribution of seabirds and coastal birds within its 12-mile-zone (Krüger *et al.*, 2003; Garthe, 2003).

This chapter focuses on coastal and marine bird species occurring in the area from the islands out to 20 m depth. The term 'coastal' applies to species only using the area off the islands to a depth of 10 m. 'Marine' species occur at larger depths. In the area off the Wadden Sea, eight species occur in numbers, which are of international importance (Table 11.1). Recently, new information on seabird distribution has been obtained due to interest in establishing wind farms in the coastal waters of the North Sea (see chapter 2.9).

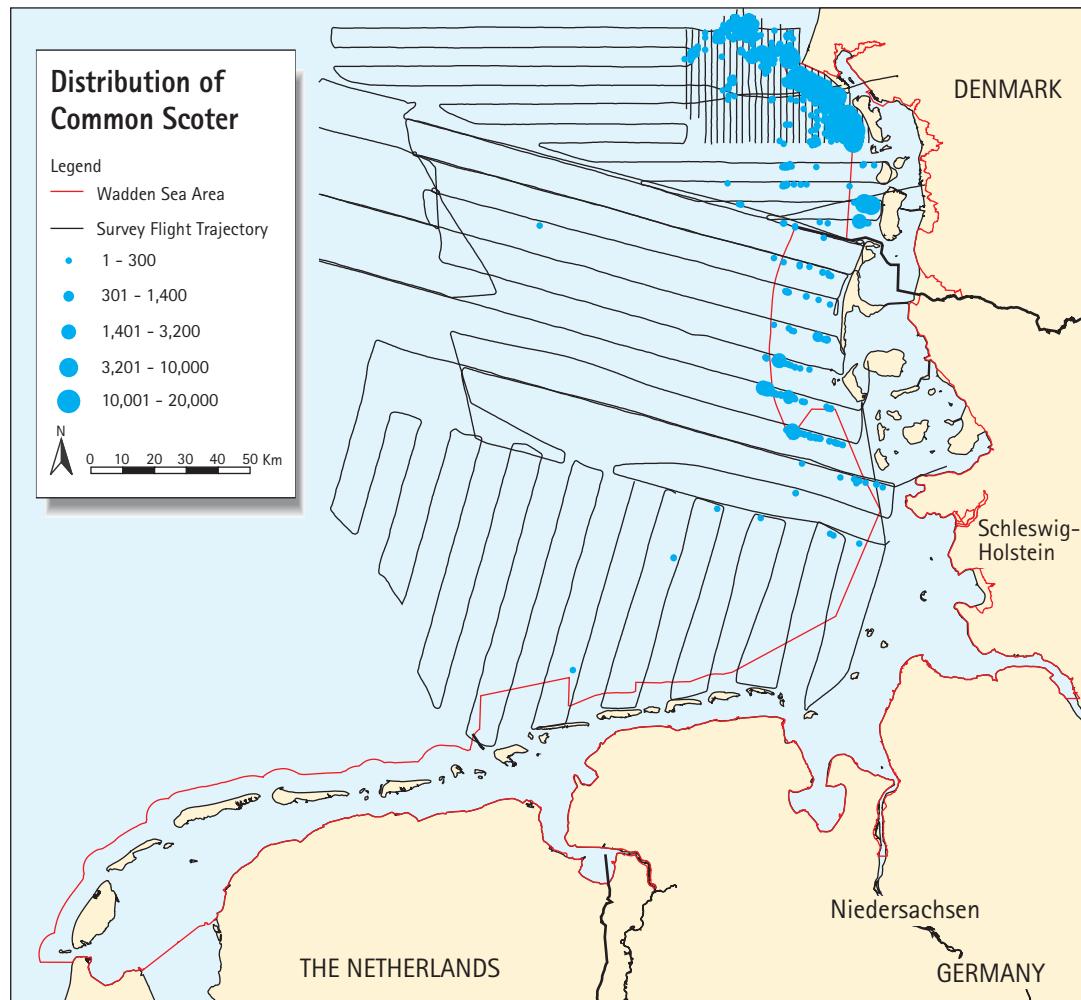
Among the 'marine' species, guillemot (*Uria aalge*) and razorbill (*Alca torda*) occur all over the North Sea outside the breeding season, feeding on small fish such as sandeels, herring and sprat. Along the West Frisian Islands they also use the coastal zone, with up to 2,000–3,000 individuals recorded. In waters shallower than 30 m they feed on small fish such as cod, herring and sprat. During the breeding season, 6,400 birds were recorded around the colony at Helgoland (Garthe, 2003). The gannet (*Morus bassanus*), is also found in the marine part of the North Sea, diving for shoaling fish. The fulmar (*Fulmarus glacialis*) is dispersed over most of the North Sea outside the breeding season, where they feed on planktonic crustaceans occurring in the upper water layer. A fraction of these birds also use the coastal zone near the Friesian Islands. The red-throated diver (*Gavia stellata*) is the most common (95%) of the divers (see photo), but the black-throated diver is also widespread (*G. arctica*) (Camphuysen and Leopold, 1994; Garthe, 2003). The divers spend the winter in the southern North Sea off the Wadden Sea in numbers up to 36,000 individuals. The majority of the divers were recorded between 4–26 m depth (Pedersen *et al.*, 2003). Aerial surveys during spring in the Danish and German sectors of the North

Sea showed that most divers occurred in the eastern parts off the Wadden Sea. 7% of the divers occurred inside, and 93% outside the Wadden Sea Cooperation Area (MINOS, NERI, Elsam Engineering A/S). In the German sector of the North Sea, up to 13,700 divers (both species) have been counted all together. The largest concentration of the divers was recorded off Sylt, outside the Wadden Sea Cooperation Area.

Of the 'coastal' species, both the lesser black-backed gull (*Larus fuscus*) and herring gull (*Larus argentatus*) breed in the Wadden Sea, and during this time of the year the largest numbers of the two species are present. The lesser black-backed gull occurs in numbers over 50,000 individuals, which is more than 25% of the total population size. Outside the breeding season, most of these birds leave the North Sea to winter along the west coast of Africa. This is opposite to the herring gull, which spreads over the North Sea outside the breeding season. During spring and the breeding season, the lesser black-backed gull is widespread and numerous far out at sea, while the herring gull has a more coastal occurrence. The lesser black-backed gull feeds at sea on fish and crustaceans, while the herring gull forages in the intertidal zone mostly on bivalves and crustaceans (Kubetzki and Garthe, 2003). The common tern utilizes the coastal parts of the Offshore Area for catching small fish. The numbers are fairly stable at 3,000 individuals.

Common scoter (*Melanitta nigra*), velvet scoter (*Melanitta fusca*) and eider (*Somateria mollissima*) use the food resources of the communities of cockles (*Cerastoderma edulis*) and clams (*Spisula subtruncata*) off the Wadden Sea. In October, the common scoter gathers off the Danish Islands, and their numbers increase during autumn to more than 300,000 individuals and their distribution expands to the whole coastal zone of the Wadden Sea (Camphuysen and Leopold, 1994; Laursen *et al.*, 1997). The largest concentrations occur off the Friesian and Danish islands, where up to 200,000

Figure 11.1:
Geographical distribution of common scoter (*Melanitta nigra*) in the SE North Sea off the Wadden Sea. The birds were monitored by aircraft in March 2002, and the flight routes are shown. Red line: Wadden Sea Area (Trilateral Cooperation Area). Data source: MINOS (Germany), National Environmental Research Institute and Elsam Engineering A/S (Denmark).



individuals can assemble (Laursen and Frikke, 1987; Garthe, 2003). Most of these birds leave for northern breeding grounds, but about 30,000 non-breeding individuals spend the summer in the Wadden Sea area. In late summer, during moulting, large concentrations of common scoters are found in the offshore zone of the three countries (see Figure 12.2.4 in chapter 12.2). Ongoing studies initiated in connection with planned and established wind farms have shown that large concentrations of common scoters occur off the Danish and the Schleswig-Holstein Wadden Sea (Figure 11.1). The majority of the scoters occurred at water depths between 2-10 m (Petersen et al., 2003). Aerial surveys during March showed that 61% of the common scoters occurred inside the Wadden Sea Cooperation Area and 39% outside (MINOS, NERI, Elsam Engineering A/S). This indicates the close connection between the Offshore Area of the Wadden Sea and the adjacent North Sea. The eider breeds in large colonies in the Wadden Sea, but during autumn also birds from the

Baltic arrive, and up to 280,000 eiders winter in the offshore zone (see chapter 12.2).

Cormorants (*Phalacrocorax carbo*) forage on the fish stock in the coastal zone during their breeding season, when they occur in flocks of several hundred individuals. These birds mostly originate from breeding colonies nearby in the Wadden Sea area. Sandwich tern (*Sterna sandvicensis*) and common tern (*Sterna hirundo*) also breed in the Wadden Sea, with the highest numbers in the months before, during and after the breeding season. The sandwich terns especially abound off the large colonies in Schleswig-Holstein and off the islands in the Elbe-Weser-Jade estuary. This species mainly feeds on sandeel (see, for example, Garthe and Kubetzki, 1998) and part of its foraging grounds are situated far offshore (up to 15-25 km from the breeding colonies). The common gull (*Larus canus*) has a similar distribution, but has its greatest abundance outside the breeding season. The little gull (*Larus minutus*) feeds on pelagic crustaceans and small fish in the upper

water layer. It arrives in August, and numbers increase to more than 2,000 individuals in December.

11.3.2.2 Connection between the Offshore Area and the Tidal Area

Winter surveys during more than ten years, of eiders in both the Dutch and the Danish parts of the Wadden Sea and the adjacent North Sea have shown that the distribution of birds shifts between the Tidal Area and the Offshore Area. During 1993–2003, in the Dutch Wadden Sea between 1 and 58% of the eiders occurred in the Offshore Area (Berrevoets and Arts, 2003). The figures were high during the late 1990s and peaked in 2000 and 2001 at 48 and 58%, respectively. In the Danish Wadden Sea, the proportion of eiders in the offshore zone varied between 2 and 77% during 1981–2001, with the highest values during 1984–1987. After 1992, the proportion of eiders in the Offshore Area fell to 12%. These figures demonstrate a close connection between the two parts of the Wadden Sea Area. The reason for the observed shift between the two parts of the Wadden Sea is not known. The striking coincidence of intensive mussel fishery and hunting activity is, however, noteworthy, and might explain the changes in distributions. Following a period of intensive mussel fishery, high eider mortality was reported from the Dutch Wadden Sea in the winter 1999/2000 (Camphuysen, 2001). In the Danish Wadden Sea, probably two reasons contributed to the change in eider distribution. The proportion of eiders in the Danish Offshore Area peaked with 54% during 1984–1987. During that period intensive blue mussel fishery also took place in the Danish Wadden Sea, and eiders shifted to the Offshore Area to feed on cockles as an alternative food source (Laursen *et al.*, 2005). In 1992, the majority of the Danish Wadden Sea was closed for hunting, which included shooting of eiders between the islands and the mainland coast. After 1992, the proportion of eiders in the Offshore Area decreased to 12%, while in the years before 1992 it was 42% (NERI data). These facts indicate that there could be more than one reason for the shifting of eiders between the Wadden Sea and the Offshore Area. The latter area can play a role both as alternative feeding area and as refuge for the eiders. For other species, however, such as the cormorant and sandwich tern, the Offshore Area is just a part of their natural feeding area.

11.3.3 Marine Mammals

These species are treated extensively in chapter 13, both for the Offshore Area and the Tidal Area of the Wadden Sea.

11.4 Management

In October 2002, the Wadden Sea was designated as a Particularly Sensitive Sea Area (PSSA). The PSSA covers a part of the Offshore Area. The PSSA classification is given to sea areas that need special protection through actions due to their significance for recognized ecological, socio-economic or scientific reasons, and which may be vulnerable to impacts from international shipping activities (Reineking, 2002). The PSSA Wadden Sea is included on the relevant sea charts and this is expected to increase shipping safety and to reduce environmental impacts. In addition, it will contribute to a more close collaboration between the different shipping authorities, which may reduce or prevent the risk of future disasters (see chapter 4.4).

Notwithstanding this progress in protection, there still are other activities in the offshore zone of the Wadden Sea, which can pose a threat to sea birds. Fishing of stocks of the clam *Spisula subtruncata* can affect the numbers of common scoter (Leopold, 1993). Studies, however, of the actual effects on common scoters have not been conducted.

Another problem for the birds could be sand extraction in the German Bight. The sandwich terns breeding on the Wadden Sea islands in large colonies feed above sand banks in the North Sea especially during the breeding period. Their preferred prey, sandeels, live on these sand banks (Garthe and Kubetzki, 1998). The effects of sand extraction on sandwich terns are not known.

The increasing interest in building wind farms brings another risk to both seabirds and sea mammals in the North Sea (Exo *et al.*, 2003). These wind farms are not allowed in the Conservation Area, but some have already been established and others are planned closed to the Conservation Area, and therefore can influence parts of the same populations that use both the Offshore Area and Tidal Area.

Exo *et al.* (2003) list five possible impacts of offshore wind farms on sea birds:

- risk of collision,
- short-term habitat loss during construction,
- long-term habitat loss due to disturbance by turbines,
- formation of barriers on migration routes, and
- disruption of ecological units, such as roosting and feeding areas.

It is recommended that the actual impact of the wind farms is assessed through detailed studies on pilot offshore wind farms. It is vital that all

potential construction sites are considered as part of an integrated assessment framework, so that cumulative effects can be carefully taken into account (Exo *et al.*, 2003).

For the selection of localities for new offshore wind farms, a planning tool is needed. For this purpose, Garthe and Hüppop (2004) suggested a 'wind farm sensitivity index' for seabirds. This index scales the risk for a large number of seabird species in relation to wind farms. It was concluded that divers, velvet scoter, sandwich tern and great cormorant are most at risk, while species such as the black-legged kittiwake, black-headed gull and northern fulmar experience the lowest risk from operational wind farms.

The data presented above shows that the Wadden Sea Area comprises only part of the geographical occurrence of the common scoter and the eider, which are the species with the highest risk in relation to wind farms. A large proportion of the common scoter occurs inside and a large proportion of the divers outside the Wadden Sea Area. These species are both listed in Annex I of the EC Birds Directive, meaning that protection of these birds is obligatory. The already designated Special Protection Areas (SPAs) and the candidate Special Areas of Conservation (cSACs) in the offshore zone according to the EC Birds and Habitats Directive will support the protection of divers in the North Sea.

11.5 Target evaluation

11.5.1 Increased natural geomorphology

The sediments of the seabed of the Offshore Area and of the channels and flats in the Tidal Area of the Wadden Sea form a coherent 'sand sharing' system. As a consequence of sea level rise, sand will be transported from the coast off the islands into the Wadden Sea. Whereas coastal defense activities on the Wadden Sea islands have continued where necessary, no major changes in geomorphology or its dynamics can be reported since the 1999 QSR. One exception is the construction in 1995 of a long cross-shore dam at the northern tip of the island of Texel, which caused sand accretion on both sides of the dam, extending the beach in a seaward direction, as well as geomorphological changes in the ebb tidal delta of the Eijerlandse Gat inlet.

11.5.1.1 Conclusions

Apart from coastal defense activities on the Wadden Sea islands (e.g. sand nourishment, cross-shore dam at Texel) no evidence has become available regarding any negative development in natural dynamics of the geomorphology of the Offshore Area

11.5.1.2 Recommendation

A monitoring scheme should be introduced for parameters in the Offshore Area to track major changes in geomorphology.

11.5.2 Favourable food conditions for birds

Repeated inventories have demonstrated the occurrence of important stocks of the bivalve *Spisula subtruncata* along the Dutch coast, and of *S. solida* along the coast of Schleswig-Holstein. These bivalves are a major food source for diving ducks such as the common scoter and eider. Especially for the eider, these *Spisula* stocks are important for the survival when other bivalve stocks in the Wadden Sea are depleted, either by severe winter conditions or by extensive shellfish fishery. In The Netherlands, there is fishery on *Spisula*, the effects of which on the common scoter and eider have not been investigated.

From the ICES North Sea Benthos Project 2000 it appears that the macrozoobenthos community in the Offshore Area is part of coastal communities along the Belgian-Dutch-German coast, characterized by low species numbers, but locality enhanced where complex substrate (sand, gravel, stones) is present, such as near Borkum Riff and in the outer Amrum grounds.

11.5.2.1 Conclusions

Bivalve stocks in the Offshore Area are important as a food resource for the common scoter, eider and other diving ducks. For the eider, *Spisula* stocks in the Offshore Area are an essential lifeline during adverse conditions in the Wadden Sea.

11.5.2.2 Recommendations

A proper management of *Spisula* fishery needs to be developed to ensure compliance with the target 'favorable food availability for birds', especially for the common scoter, eider and velvet scoter.

11.5.3 Viable stocks of common seal, grey seal and harbour porpoise

For the evaluation of the target regarding sea mammals, the reader is referred to chapter 13.

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12. Birds

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Lieuwe Dijkse
Bernd Hälterlein
Karsten Laursen
Petra Potel
Peter Südebeck
Jan Blew
Kai Eskildsen
Klaus Günther
Hans-Ulrich Rösner
Marc van Roomen

12.1 Breeding Birds



Kees Koffijberg
Lieuwe Dijken
Bernd Hälterlein
Karsten Laursen
Petra Potel
Peter Südbeck

Oystercatcher
(Photo: M. Stock)

12.1.1 Introduction

The Wadden Sea attracts many coastal breeding birds, such as the Eurasian spoonbill *Platalea leucorodia*, avocet *Recurvirostra avosetta*, kentish plover *Charadrius alexandrinus* and gull-billed tern *Gelochelidon nilotica*, for which the Wadden Sea is a hot spot within the European breeding range and which represent Species of European Concern. Furthermore, 14 species are included in Annex I of the EC Birds Directive and several breeding birds are listed in national Red Lists for Denmark, Schleswig-Holstein, Niedersachsen or The Netherlands. The distribution of breeding birds within the Wadden Sea is mainly determined by geographical range, feeding opportunities, available nesting habitat, predation pressure and level of human disturbance. High densities of breeding birds are especially found at the salt marshes, the dunes at the islands and the higher outer sands. Breeding bird surveys in the Trilateral Monitoring and Assessment Program (TMAP) include annual counts of colonial and rare breeding birds and annual counts of common bird species in representative sample areas. Additionally, once every five years (1991, 1996, 2001, etc.), a complete survey of all breeding birds in the Wadden Sea is carried out. These surveys follow standardized guidelines for fieldwork and data collection (Hälterlein *et al.*, 1995).

The trilateral policy concerning bird populations in the Wadden Sea have been addressed in the Wadden Sea Plan and is formulated as the following Targets:

Targets
Favorable conditions for breeding and migratory birds:

- favorable food availability *
- natural breeding success *
- sufficiently large undisturbed roosting and moulting areas
- natural flight distances

* mainly relevant for breeding birds

12.1.2 Quality Status Report 1999

As shown in the 1999 QSR, trends in breeding bird numbers vary among species. Long-term upward trends were found, for example, for the great cormorant and Eurasian spoonbill, which have both expanded their breeding range in the past decades and increasingly breed in the Wadden Sea. Furthermore, breeding bird populations at salt marshes have changed as a result of abandoned livestock-grazing of coastal salt marshes in the 1980s and 1990s, especially in Niedersachsen and Schleswig-Holstein (Remmers, 2003; Stock, 2003). Species favoring higher vegetation to breed, such as redshank, several ducks and many passerines benefited from these changes and increased at many sites (Hälterlein, 1998; Thyen, 2000; Schrader, 2003; Hälterlein *et al.*, 2003; Oltmanns, 2003). On the other hand, a few species preferring short vegetation experienced declines in several areas, e.g. the northern lapwing *Vanellus vanellus*. Downward trends were also observed for birds which rely on

undisturbed beach habitats and primary dunes, such as the great ringed plover *Charadrius hiaticula* and the kentish plover. These breed at a limited number of sites, which are often abandoned when (natural) vegetation succession proceeds. As a result, these bird species suffer from lack of breeding areas with high natural dynamics. Moreover, their breeding sites often overlap with preferred sites for recreational activities and unless special conservation measures are taken, the birds are often highly susceptible to human disturbance.

12.1.3 Data collection

This chapter presents the results of the most recent complete breeding bird survey, in 2001, and provides information on trends in 1991–2001 and

recent developments in 2002–2003. This data has been derived from the annual census of colonial and rare breeding birds, and from the annual common breeding bird census in sample areas (Fleet *et al.*, 1994; Melter *et al.*, 1997; Rasmussen *et al.*, 2000; Dijksen *et al.*, in prep.). These surveys focus on ducks, coastal waders, gulls and terns, as well as some colonial breeding birds (great cormorant, Eurasian spoonbill) and two raptors (hen harrier *Circus cyaneus* and short-eared owl *Asio flammeus*) (see Table 12.1.1). For rare dune-breeding passerines such as wheatear *Oenanthe oenanthe* and red-backed shrike *Lanius collurio* (cf. chapter 9.2) only a little data is available from the sample areas, and therefore this does not allow any trend

Breeding birds in the Wadden Sea in 2001 and trends in 1990–2001 (after Dijksen *et al.*, in prep.). Also given are international importance (expressed as percentage of the overall NW-European flyway population, after Rasmussen *et al.*, 2000) and Red List status (Wadden Sea, SUS susceptible; VUL vulnerable; END Endangered; CRI critical; – no red list status, according to Rasmussen *et al.*, 1996). 2001 numbers refer to the breeding population in 2001. Trends are shown for the entire period 1991–2001 and for the last 5 years (since 1996) to detect recent changes: – significant decrease; = significant stable; (=) fluctuating without significant trend; + significant increase (significant at $P < 0.05$).

For some species no trend could be calculated due to the small or scattered breeding population ('no data'). Species included in Annex I of the EC Birds Directive are marked separately. For species marked with * a summary of national trends is given in Table 12.1.2.

Species	Annex I		Red List Status	2001 numbers	Trend 1990–2001	Trend 1996–2001
	EC Birds Directive	% population NW-Europe				
Great cormorant <i>Phalacrocorax carbo</i>	–	1–5	–	2,348	+	+
Eurasian spoonbill <i>Platalea leucorodia</i>	x	>25	SUS	831	+	+
Shelduck <i>Tadorna tadorna</i> *	–	5–25	–	6,480	+	+
Common eider <i>Somateria mollissima</i> *	–	1–5	–	10,500	+	(=)
Red-breasted merganser <i>Mergus serrator</i>	–	<1	VUL	44	(+)	no data
Hen harrier <i>Circus cyaneus</i>	x	1–5	–	126	(=)	–
Oystercatcher <i>Haematopus ostralegus</i> *	–	5–25	–	39,928	(=)	–
Avocet <i>Recurvirostra avosetta</i> *	x	>25	–	10,170	=	(=)
Great ringed plover <i>Charadrius hiaticula</i> *	–	1–5	VUL	1,093	–	–
Kentish plover <i>Charadrius alexandrinus</i> *	x	>25	END	340	–	–
Northern lapwing <i>Vanellus vanellus</i> *	–	1–5	–	11,643	–	(=)
Dunlin <i>Calidris alpina schinzii</i>	x	1–5	CRI	24	(-) ¹	no data
Ruff <i>Philomachus pugnax</i>	x	<1	CRI	33	(-) ¹	no data
Common snipe <i>Gallinago gallinago</i>	–	<1	–	188	(-) ¹	no data
Black-tailed godwit <i>Limosa limosa</i>	–	1–5	VUL	2,824	–	(=)
Eurasian curlew <i>Numenius arquata</i>	–	<1	–	640	(=)	(=)
Common redshank <i>Tringa totanus</i> *	–	5–25	–	17,815	(=)	(=)
Turnstone <i>Arenaria interpres</i>	–	<1	CRI	1	no data	no data
Mediterranean gull <i>Larus melanocephalus</i>	x	1–5	–	9	+	+
Little gull <i>Larus minutus</i>	x	<1	SUS	–	no data	no data
Black-headed gull <i>Larus ridibundus</i> *	–	5–25	–	154,395	(=)	+
Common gull <i>Larus canus</i> *	–	1–5	–	13,827	+	+
Lesser black-backed gull <i>Larus fuscus</i> *	–	5–25	–	79,679	+	+
Herring gull <i>Larus argentatus</i> *	–	5–25	–	78,402	–	(=)
Great black-backed gull <i>Larus marinus</i>	–	<1	–	27	+	+
Gull-billed tern <i>Gelochelidon nilotica</i>	x	>25	CRI	56	(=)	(=)
Sandwich tern <i>Sterna sandvicensis</i> *	x	>25	END	17,172	=	(=)
Common tern <i>Sterna hirundo</i> *	x	5–25	–	13,594	–	+
Arctic tern <i>Sterna paradisaea</i> *	x	1–5	–	8,464	+	–
Little tern <i>Sterna albifrons</i>	x	>25	END	1,099	+	+
Short-eared owl <i>Asio flammeus</i>	x	<1	END	89	(=)	(=)

¹ trend calculation was not possible due to lack of data; classification (see caption) is based on the results of the surveys in 1991, 1996 and 2001.

evaluation. The main topics to be addressed in this chapter are the current status of breeding birds in the Wadden Sea and trends in the past decade. Trends are reviewed with respect to human impact (disturbance, fisheries, salt-marsh management/agriculture, climate changes, chemical pollution) and natural processes (overall population trends, predation, competition between species).

12.1.4 Status of breeding birds in 2001

Among the 31 bird species included in the monitoring program are 23 species for which the Wadden Sea supports at least 1% of the NW-European population (Rasmussen *et al.*, 2000; Table 12.1.1), many of them also listed as Annex I species in the EC Birds Directive. Of six species, even more than 25% of the NW-European population is involved. Regarding numbers, some colony-breeding gulls such as the black-headed gull *Larus ridibundus*, lesser black-backed gull *Larus fuscus* and herring gull *Larus argentatus* as well as the oystercatcher *Haematopus ostralegus* are the most common breeding birds. Other abundant species are common eider *Somateria mollissima*, avocet, northern lapwing, common redshank *Tringa totanus*, common gull *Larus canus*, sandwich tern *Sterna sandvicensis* and common tern *Sterna hirundo*. Among the rare breeding birds are dunlin *Calidris alpina schinzii* and ruff *Philomachus pugnax*,

which have been subject to long-term declines and are currently hovering on the verge of extinction. For the red-breasted merganser *Mergus serrator*, turnstone *Arenaria interpres*, Mediterranean gull *Larus melanocephalus* and little gull *Larus minutus* the Wadden Sea is currently situated at the edge of their European breeding range, and only scattered and often fluctuating numbers of breeding pairs are observed.

12.1.4.1 Overall trends

Thanks to nearly 15 years of Joint Monitoring of Breeding Birds (JMBB) – since 1994, as part of the TMAP – a reliable evaluation of trends has become possible, both for the entire period as for the last five years. The latter can be used as an alert for recent changes (Table 12.1.1). Overall trends for the entire Wadden Sea for 1990–2001 show significant increases in ten species (eleven if the red-breasted merganser is included). The highest rates of increase are observed for the great cormorant, great black-backed gull *Larus marinus*, Eurasian spoonbill, lesser black-backed gull and Mediterranean gull (Figure 12.1.1). Nearly all these species have expanded their geographical breeding range in the past decade and showed further increases in 2002–2004. The breeding population of many increasing species continued to grow during the entire period covered by the surveys. Exceptions are the common eider and arctic tern.

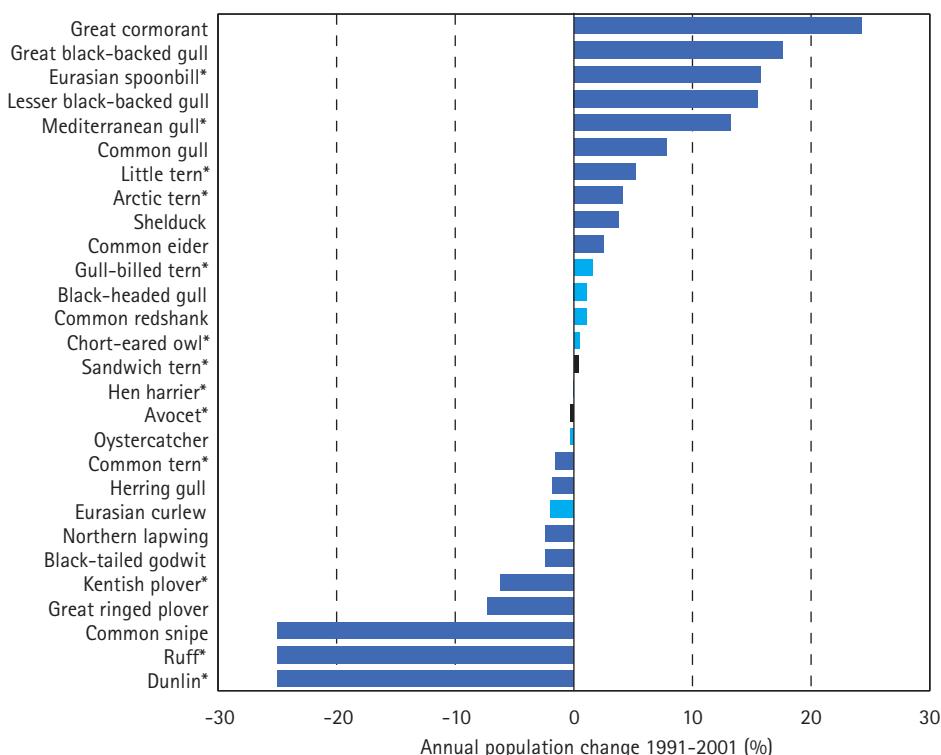


Figure 12.1.1:
Summary of trends for breeding birds in the Wadden Sea between 1991–2001. Given is the annual rate of increase or decrease (in %). Non-significant changes are marked in light blue. Black bars indicate species with significant stable trend and annual changes of nearly zero. For common snipe, ruff and dunlin, the rates of decline could not be calculated from the census data and have been assumed to be >25% considering the data from the complete surveys in 1991, 1996 and 2001. Species included in Annex I of the EC Birds Directive are marked with an asterisk (*).

Table 12.1.2:
Summary of trends in Denmark, Schleswig-Holstein, Niedersachsen and The Netherlands 1990–2001 in 15 common species for which trend calculation was possible (marked with * in Table 12.2.1). Given is the number of species in each trend category. Trend classification is according to Table 12.1.1.

Trend indication	Denmark	Schleswig-Holstein	Niedersachsen	The Netherlands
sign. increase +	10	10	8	4
fluctuating (=)	3	-	1	4
sign. stable =	-	1	-	-
sign. decrease -	2	4	6	7

For the common eider, the initial population growth has leveled off and fluctuating numbers (with tendency to decline) dominate after 1996. The arctic tern has decreased since 1998, but still breeds in higher numbers as compared to the early 1990s.

Significant declines have occurred in nine species, among them the great ringed plover, kentish plover, black-tailed godwit *Limosa limosa* and northern lapwing. The most dramatic declines seem to have occurred in three species for which proper trend calculations in the past decade are difficult to assess due to low numbers and scattered breeding. Dunlin, ruff as well as common snipe have all probably declined by more than 50% when considering the past decades, and both dunlin and ruff are likely to disappear from the Wadden Sea in the near future (Rasmussen et al., 2000). Recent counts suggest that the rate of decline of the northern lapwing, black-tailed godwit and herring gull has leveled off, whereas a recovery has become apparent for the common tern recently. The great ringed plover and kentish plover continued to decline in 2002–2004.

12.1.4.2 Regional trends

Trends, especially for those species for which they are marked, are often consistent throughout the Wadden Sea, e.g. the great ringed plover (decreasing), and the common gull, lesser black-backed gull, arctic tern and little tern (all increasing). The same applies to species which occur in only a limited part of the area, such as great cormorant. However, there are also obvious differences between Denmark, Schleswig-Holstein, Niedersachsen and The Netherlands (Table 12.1.2). The highest numbers of declining species are found in The Netherlands (seven out of 15 species considered) and Niedersachsen (six out of 15 species). Often, these include birds which are thriving or fluctuating in Schleswig-Holstein and Denmark, such as avocet and herring gull. In The Netherlands, this also concerns, for example, the oystercatcher, northern lapwing and black-headed gull, which are all experiencing significant declines, in contrast to growing or fluctuating numbers elsewhere. Furthermore, common redshank numbers in Niedersachsen decreased over 1990–2001, whereas in other sections of the Wadden Sea the population

is growing or does not show a clear trend. Obvious differences within the Wadden Sea are also found for the hen harrier and short-eared owl, which show declines on the Dutch Wadden Sea islands (see also chapter 9.2), but are increasing on the islands in Niedersachsen. In many cases, the processes involved here are not known in detail and need further investigations beyond the monitoring program to unravel some of the causes. For some species, differences in national management can probably explain the observed trends. For others, it merely reflects natural population dynamics, such as the expansion of the breeding range, as in the case of the Eurasian spoonbill, Mediterranean gull and great black-backed gull, which have invaded the Wadden Sea from the southwest (Eurasian spoonbill and Mediterranean gull) or the northeast (great black-backed gull). In the sections below, some of the aspects influencing breeding bird numbers are highlighted and discussed.

12.1.5 Factors influencing breeding birds

12.1.5.1 Climate changes

During the past decades, growing evidence has been collected that human activities have increased the amount of greenhouse gases and initiated global warming (see chapter 3). As a result, air temperatures are expected to increase in the next decades. Concerning breeding birds in the Wadden Sea, potential threats are imposed by sea level rise and increased storminess, which are likely to enhance the risk of inundations of salt marshes, beaches, outer sands and other exposed breeding sites and thus might affect breeding habitats and breeding success. On the other hand, the tendency for milder winters might enhance survival of birds wintering in and around the Wadden Sea, although there is also evidence that the quantity and quality of food for birds may deteriorate as a result of temperature rise, posing an extra constraint on the winter survival of birds (cf. chapter 3 and 8.2). Since such developments will proceed mainly on a gradual scale, it is difficult to assess whether bird numbers until now have been affected by climate changes. Although flooding of salt marshes occurred several times in the 1990s, there is no clear increasing trend in flooding-

events (Rasmussen *et al.*, 2000). Especially vulnerable to flooding are those species which preferably breed on dynamic and sparsely vegetated areas, e.g. salt marsh edges, beaches and primary dunes. Several of these species show decreasing numbers of breeding pairs (e.g. great ringed plover, kentish plover, avocet at local scale), but there is evidence that currently they rather suffer from increased recreational pressure (see below), loss of natural dynamics of their breeding habitat and predation. The avocet, for which reproductive output (mainly survival of chicks) strongly depends on floodings and weather conditions during the chick rearing period, might be at risk when the climate continues to change and weather during the breeding season deteriorates. This species is especially vulnerable since its chicks mainly feed on bare mudflats without any shelter, where they are susceptible to rain, wind and low temperatures (Hötker and Segebade, 2000).

12.1.5.2 Chemical pollution

As a result of contamination with organochlorine pesticides, several coastal breeding birds such as gulls and terns experienced dramatic declines in the 1950s and 1960s. Even today, the population of sandwich terns in the Dutch Wadden Sea is still believed not to have recovered completely from this crash. As assessed by monitoring of pollutant concentrations in the Wadden Sea in the 1980s and 1990s, the situation has much improved; concentrations are now below levels where impact on the reproductive output in the Wadden Sea can be expected (see chapter 4). For some breeding birds, however, particularly the common tern, some key spots with significantly higher contaminant concentrations still occur, especially in the Elbe estuary. Since this is confined to limited areas, it is unlikely that the population decline of the common tern which is being observed in large parts of the Wadden Sea is caused by pollution. However, recent increases in chemical pollution (see chapter 4) require continued and careful monitoring in years to come.

12.1.5.3 Outdoor recreation

As already pointed out in the 1999 QSR, conflicts between recreation and breeding birds occur especially for species which breed mainly on beaches and primary dunes, which are locations preferred for recreation. As a result, long-term declines have occurred in the great ringed plover, kentish plover and little tern (Fleet *et al.*, 1994; Rasmussen *et al.*, 2000). The great ringed plover and kentish plover continued their downward trend in nearly all parts of the Wadden Sea be-

tween 1990 and 2003. This is partly due to the reduction of numbers in the more recently embanked wetlands in Denmark and Schleswig-Holstein, which, due to vegetation succession, have become less attractive for plovers and other pioneering bird species (Rasmussen *et al.*, 2000; Hälterlein *et al.*, 2000). These species still also find limited possibilities to breed in their preferred habitat as a result of recreational pressure at these sites. Several studies have shown that human disturbance reduces opportunities to settle territories and affects breeding success (Tulp, 1998; Schulz, 1998). For the little tern *Sterna albifrons*, which breeds in distinct colonies, protective measures have been implemented at many breeding sites since the 1980s (Hälterlein, 1996; Flore, 1997; Witte, 1997; Potel *et al.*, 1998) and have initiated a population recovery in all parts of the Wadden Sea. For both plover species, which breed in a more scattered and isolated pattern, management measures have been not very successful so far, as they were not taken on a wide scale and thus had only effect on some local breeding populations. For management measures to succeed, local support is essential. In a project currently being carried out in the Dutch Wadden Sea, (island) municipalities, scientists, conservationists and site managers of nature reserves collaborate in order to limit disturbance at the breeding sites (Kersten, 2004).

12.1.5.4 Fisheries

Two aspects of fisheries have influenced trends in breeding birds in the Wadden Sea in the past decades. The population growth of the lesser black-backed gull is to some extent regarded as having been facilitated by increased fishery discards (Garthe *et al.*, 1996; Spaans, 1998a). The herring gull benefited from this food resource as well, but changed its feeding habits in the 1960s and has switched to benthic prey in the intertidal area, as well as to waste dumps, from the 1970s onwards (Noordhuis and Spaans, 1992; Spaans, 1998b). Although the amount of discards has decreased recently in some fisheries, it is not clear yet whether this affects current population trends in both gulls (S. Garthe, pers com.). Lesser black-backed gull numbers are still increasing in all parts of the Wadden Sea, whereas the herring gull has experienced major declines, especially in its core breeding areas of The Netherlands and Niedersachsen. It is not clear whether the herring gull suffers from competition from lesser black-backed gulls. In some colonies, evidence for such a competition exists (Noordhuis and Spaans, 1992), in other colonies evidence is lacking (Garthe *et al.*, 2000). It is more likely that the decreased accessibility of

Common redshank
(Photo: K. Janke)



waste dumps has affected food availability for herring gulls recently (Spaans 1998b). Moreover, the species might also be influenced by mussel fisheries. Since the herring gull often takes blue mussels *Mytilus edulis* (Noordhuis and Spaans, 1992; Kubetzki and Garthe, 2003), the depletion, or even the complete removal, of natural mussel beds in parts of the Wadden Sea by fisheries in the early 1990s may have been detrimental to herring gulls in the past decade (Leopold *et al.*, 2004).

Extensive exploitation of mussel beds and also cockle *Cerastoderma edule* stocks in the Dutch part of the Wadden Sea is one of the main explanations for the reduced numbers of common eiders and oystercatchers in this part of the Wadden Sea (Camphuysen *et al.*, 2001; Rappoldt *et al.*, 2003; Leopold *et al.*, 2004; Verhulst *et al.*, 2004). For the oystercatcher, the decline of the population (both non-breeders and breeding birds, see also chapter 12.2) was initiated by the severe winter of 1995/96, which caused mass-mortality in the Dutch Wadden Sea. The population did not recover, as food stocks were low due to the removal of blue mussel beds by mussel fisheries in the early 1990s. As a result, oystercatchers became more dependent on cockle stocks and increasingly had to compete with mechanical cockle fisheries. Recently, a decline in oystercatcher numbers has also become apparent in Niedersachsen from 1997 onwards, but it is not clear to what extent this is linked to

the situation in the Dutch Wadden Sea or to local developments in mussel fisheries in Niedersachsen. Similarly to the oystercatcher, numbers of common eider have declined as a result of the decreased stocks of blue mussels in the Dutch Wadden Sea (Camphuysen *et al.*, 2001; Oosterhuis and van Dijk, 2001; Ens and Kats, 2004).

12.1.5.5 Agriculture and salt marsh management

Until the 1980s, large parts of the (mainland) salt marshes in the Wadden Sea were subject to agricultural activities. With the establishment of national parks in the German Wadden Sea and the implementation of trilateral policies aiming at natural salt marshes, an increasing part of the salt marshes have become dominated by a natural morphology and vegetation development (Remmers, 2003; Stock, 2003; see also chapter 7). Throughout the Wadden Sea, several studies have dealt with the response of breeding birds to these management changes. In general, lower agricultural pressure or abandonment of livestock-grazing enhances breeding opportunities for species preferring tall vegetation, for example ducks such as the shoveler *Anas clypeata*, the redshank, skylark *Alauda arvensis*, meadow pipit *Anthus pratensis*, yellow wagtail *Motacilla flava*, reed bunting *Emberiza schoeniclus* and other passerines (Hälterlein 1998; Eskildsen *et al.*, 2000; Esselink, 2000; Thyen, 2000; Schrader, 2003; Oltmanns, 2003; Thyen and Exo, 2003; Hälterlein *et al.* 2003). At some sites, an increase of black-tailed godwit was also reported (re-colonization in Schleswig-Holstein after abandonment of grazing) (Eskildsen *et al.*, 2000), whereas other studies, especially in Niedersachsen, suggest that this species, as well as the northern lapwing, does favor some agricultural activities (e.g. hay-making) and prefers the associated shorter vegetation (Thyen, 2000; Oltmanns, 2003; Hälterlein *et al.* 2003). Species such as avocet also avoid tall vegetation and may disappear from areas in which livestock-grazing ceased (Hälterlein 1998; Thyen, 2000). This species is also known to benefit from the maintenance of the artificial drainage system, which frequently provides sparsely vegetated zones and delays vegetation succession in parts of the salt marshes (Koopman, 2003).

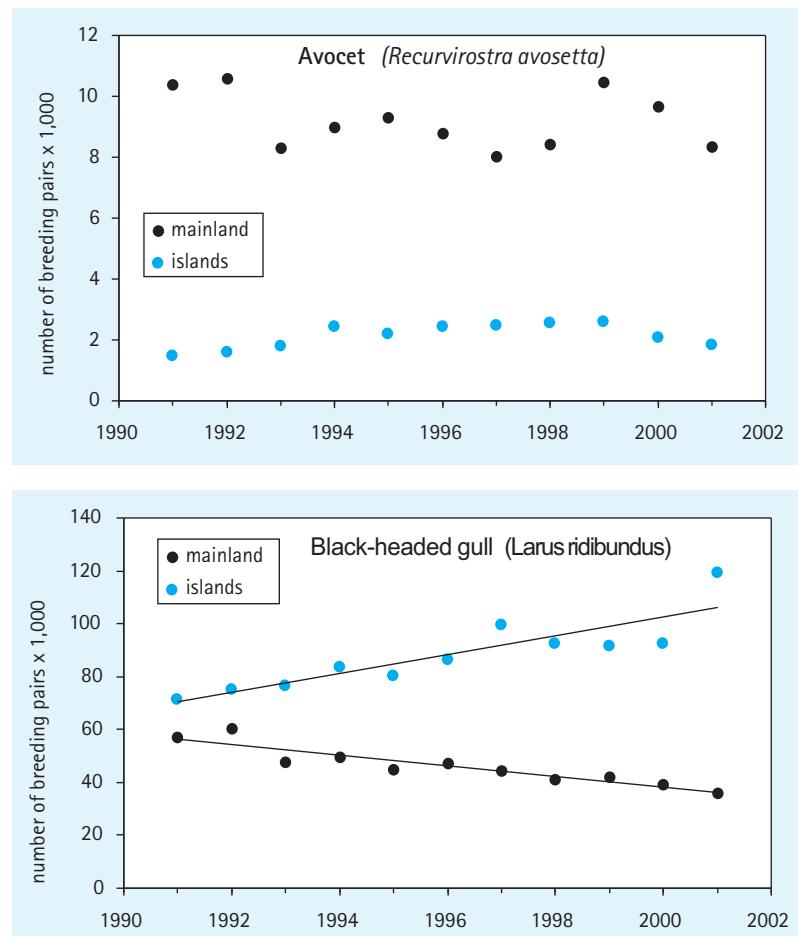
Among the breeding birds assessed, the oystercatcher, avocet, northern lapwing, black-tailed godwit and common redshank occur in highest densities at salt marshes (Rasmussen *et al.*, 2000). Trends for these species indicate declines (northern lapwing, black-tailed godwit) or show stable/

fluctuating numbers (oystercatcher, avocet, common redshank), (Table 12.2.1; Figure 12.1.1). It is difficult, however, to attribute these developments to changes in salt marsh management, since many other processes may affect these species as well. Many of the abandoned salt marshes are still situated in a transition zone between entirely man-dominated and natural salt marsh processes. Thus, current breeding bird populations are still dynamic and changes will become more pronounced in future years.

For the avocet and oystercatcher, the main causes for the population decline in parts of the Wadden Sea are thought to be connected to increased predation pressure (see below) and shellfish fisheries, respectively. Northern lapwing, so far, have only showed a clear decline in The Netherlands, where indeed in large parts of the mainland salt marshes a decrease in agricultural use was noted recently (Koopman, 2003). However, declines in northern lapwing numbers are also reported from many inland agricultural areas (Rasmussen and Laursen, 2000; SOVON, 2000; OAG, 2001; Berndt *et al.*, 2002; Melter, 2004) where this species (and also oystercatcher, black-tailed godwit and common redshank) has failed to cope with the ongoing intensification of agricultural practice. The black-tailed godwit occurs in larger numbers only in Denmark, Niedersachsen and The Netherlands. Except for Denmark (where it is fluctuating without a clear trend), this species shows a downward trend. Also here, local declines might be a result of changes in salt marsh management, but on the other hand, for this species too, the negative trend in the Wadden Sea coincides with a contraction of the breeding range in agricultural areas further inland. The Wadden Sea, therefore, can hardly be considered to be a refuge for these species anymore, as assumed by Rasmussen *et al.* (2000). The common redshank, which has shown a positive response to a decrease in agricultural use of salt marshes, shows varying trends throughout the Wadden Sea. In Denmark and Schleswig-Holstein, numbers grew between 1990–2001, but in The Netherlands they fluctuated, and in Niedersachsen even declined (especially after 1995).

12.1.5.6 Predation

Many coastal breeding species have encountered an increase in predation rates in the past decade (Rasmussen *et al.*, 2000; Koopman, 2003). In particular, the thriving population of red foxes *Vulpes vulpes* at many sites along the mainland Wadden Sea coasts (incidentally also islands, e.g. Langli in Denmark) has affected the population develop-



ment and distribution of, for example, the avocet and black-headed gull recently (Hötker and Segebäde, 2000; Rasmussen *et al.*, 2000; Koopman, 2003; Oltmanns, 2003). As a consequence, colonies of black-headed gulls have recently tended to switch to the islands but remain stable in overall numbers (Figure 12.1.2). A similar development has been reported for the common tern in the Dutch Wadden Sea (Dijksen and Koks, 2003) and Niedersachsen. An exception here is the Elbe estuary, with opposite trends on the islands (Trischen, Scharhörn) to the mainland salt marshes in the southern part of Schleswig-Holstein (Südbeck *et al.*, 1998; Garthe *et al.*, 2000). On the islands, red foxes and other mammalian predators (notably *Mustelidae*) are normally absent and some temporary predation pressure only has to be expected from brown rats *Rattus norvegicus*. However, in the case where islands are connected to the mainland coast by dams (as is the case for Sylt), predators can easily invade the islands. As shown on Sylt, some years after the settlement of mammalian predators, populations of coastal breeding birds crashed.

Figure 12.1.2: Population trends of avocets and black-headed gulls breeding at sites along the mainland coast and at islands (incl. outer sands). For black-headed gull, both trends are significant (regression lines for mainland: $R^2=0.857$, $P<0.001$; islands $R^2=0.763$, $P<0.001$); for avocet both trends were not significant.

Avocet
(Photo: J. Frikke)



The avocet, in contrast to the black-headed gull, is not able to compensate for its decreases along the mainland coast by breeding on islands (Figure 12.1.2), although a slight, but non-significant, increase in the breeding population on islands is apparent. According to Koks and Hustings (1998) island populations of avocet have a very low reproduction rate, probably because they have to feed on the less attractive sandy tidal flats around the islands. So far, the general trend for the avocet in the Wadden Sea does not seem to be threatened by predation pressure. Moreover, the avocet is a highly mobile species, which easily settles in newly created areas, both natural and artificial. Examples of developments of artificial sites were the embankments in Denmark and Schleswig-Holstein in the 1980s and 1990s (Fleet *et al.*, 1994; Hälterlein, 1998; Rasmussen *et al.*, 2000). Recently, large numbers of avocet (up to 800 breeding pairs in 2003) bred in the Dutch polder Breebaart (re-connected to the Ems-Dollard estuary in 2000), which probably attracted birds from the German part of the Dollard (B. Oltmanns and K. Koffijberg, unpublished) as well as foreign breeders. Among the latter were individuals which were ringed as juveniles in southern Spain (R. Oosterhuis and A. Boven, pers. comm.). In a reverse development, juveniles from Schleswig-Holstein have been found breeding in Spain, France and the British Isles (Südbeck and Hälterlein, 1999), showing the high mobility of the species in exchanging between breeding sites, and its adaptations to survive in highly dynamic environments like the Wadden Sea.

12.1.6 Target evaluation

Considering the trilateral targets of the Wadden Sea Plan for breeding birds, the status of several breeding species is still a matter of concern. Regarding the target of 'favorable food availability', declines in populations of common eider, oystercatcher and probably also herring gull in (mainly) the Dutch Wadden Sea point to an ongoing conflict between natural values and economical interests, notably shellfish fisheries in the Dutch part of the Wadden Sea. These negative trends coincide with a simultaneous decline in numbers of non-breeding birds (at least for the oystercatcher, Blew and Südbeck, 2005, see chapter 12.2). Although Dutch policies concerning mussel and cockle fisheries have taken into account reservations for food for these species, these measures were not able to halt the downward trend. The favorable availability of food is further constrained by the occurrence of severe winters, which increases winter mortality. Previously, oystercatcher numbers were able to recover from severe winters, but since the mid 1990s they have remained at low population levels. It is expected that in the current situation, a severe winter in one of the coming years will lead to a further population decline in this species. Common eider have compensated for lower food stocks in the Dutch Wadden Sea to some extent by feeding on less profitable *Spisula* banks in the adjacent coastal zone of the North Sea, but continue to be threatened as long as the current fishery practices continue, especially since fisheries on *Spisula* also increased recently. This is of major concern, since more than 75% of all breeding common eiders in the Wadden Sea are

confined to the Dutch section. To what extent other breeding birds are affected by deteriorating food availability is not clear yet. Analyses of non-breeding birds show distinct trends between bivalve-specialists like the oystercatcher and red knot (declining) and worm-specialists like the dunlin and bar-tailed godwit *Limosa lapponica* (increasing).

Considering the target of a 'natural breeding success', there is still a need for comprehensive protection measures for beach-breeding species, especially the great ringed plover and kentish plover. These species suffer from recreational activities, which prevent them from successfully breeding at many of their preferred breeding sites. This situation has not changed since the 1999 QSR and the Esbjerg Declaration (2001), where it was stated that these species are particularly vulnerable during breeding and therefore efforts to reduce the amount of human disturbance at the breeding sites should be undertaken. Measures that have been taken were implemented on a sporadic and local scale only, which is not satisfactory. Both species show ongoing declines in all parts of the Wadden Sea. The need for conservation measures at their primary habitats has now become even more urgent since breeding habitats in, for example, embanked wetlands and some mainland salt marshes have changed as a result of vegetation succession. In contrast, for the little tern, conservation measures to prevent human disturbance have proven to be very well able to reverse the downward trends when implemented on a large enough scale. The little tern has recovered in nearly all parts of the Wadden Sea since measures were taken in the 1980s and 1990s.

12.1.7 Conclusions

The trilateral surveys of breeding birds carried out since 1990 enable an evaluation of trends over a period of more than ten years. Out of 31 species considered, eleven have increased in number, among them species for which the Wadden Sea serves as a core breeding area and which are considered vulnerable, such as the Eurasian spoonbill. Numbers of this species have continued to increase since the 1999 QSR. Many species showing upward trends have been subject to a general population expansion in the past decade. As a consequence, the developments in the Wadden Sea must be regarded as an expression of an overall population growth (e.g. for the great cormorant, lesser black-backed gull, Mediterranean gull). However, for the beach-breeding kentish plover and great ringed plover the situation is still unsatisfactory, a problem which was already ad-

dressed in the 1999 QSR. Although on a local scale achievements have been made, measures taken have not been successful in halting the overall decline. There is also evidence that in the near future visitor numbers will increase, causing increasing conflicts with the target. For the little tern, measures to prevent human disturbance at breeding sites have been successful in reversing downward trends. However, for the great ringed plover and kentish plover measures will only be effective when taken on a scale large enough to cover an important part of the population. Moreover, management should anticipate the changing distribution of breeding sites caused by natural vegetation succession. Therefore, an inventory of (potential) key breeding sites and their bottlenecks concerning natural dynamics and human disturbance should be carried out in all sections of the Wadden Sea, followed by the implementation of strict and practical conservation measures. This should include simple guidance to visitors in order to increase local support of the measures taken.

Downward trends in the Eurasian oystercatcher, common eider (recent decline) and perhaps also herring gull, at least in the Dutch section of the Wadden Sea, point to a deviation from 'favorable food availability' (cf. chapter 12.2). This fact was already put forward in the 1999 QSR, but has remained a bottleneck, also since the new management scheme for shellfish fisheries (notably cockle fisheries) in recent years in the Dutch Wadden Sea was not able to reverse the downward trends for species such as the Eurasian oystercatcher. In the 1980s, similar developments in the Danish Wadden Sea led to major restrictions in blue mussel fishery. The decision of the Dutch government to definitively stop mechanical cockle fisheries from 2005 onwards (cf. chapter 12.2) is a major step towards the trilateral target of a favorable food availability. The impact of shellfish fisheries in The Netherlands and in Denmark shows, however, that management of the remaining shellfish fisheries (mainly targeted at blue mussels) should continue to carefully review this activity against the background of favorable food availability for birds.

A new aspect since the 1999 QSR is predation of breeding birds, mainly by small mammals. Predation has especially affected breeding sites at the mainland, and focuses on coastal waders and colony-breeding species such as gulls and terns. As a result, populations of some species (e.g. black-headed gull) have shifted from mainland breeding sites to the islands, where predators are scarce

or even absent. Especially for colonial breeding birds, it is important to maintain the current predator-free status of most of the islands and prevent any further human-influenced settlement of mammalian predators. Plans for improving existing dams to islands, as recently proposed for the Hallig Oland in Schleswig-Holstein, should be treated with caution, since it could easily facilitate predators moving from the mainland to the islands, and (in the case of Oland) increase the risk for a raid on, for example, the local spoonbill colony. Active management of predators (e.g. by hunting) will be extremely difficult in the Wadden Sea since they occur on a very wide scale, vacant territories for territorial animals (e.g. red foxes) will be easily taken over by new individuals and hunting in the Wadden Sea should be avoided as it causes too much disturbance to, for example, roosting birds (see also chapter 12.2).

For many other species, the underlying causes of the assessed trends are not clear. A major bottleneck in the interpretation and explanation of the observed trends is the lack of data on reproduction and survival. Monitoring of populations is a powerful instrument to detect changes in numbers, but is insufficient alone to unravel the causes of the trends observed. Moreover, a response of a population to changes in its environment will be delayed in many cases, but will become visible earlier when parameters regarding breeding success and mortality rates can also be taken into account. Now, such information is available only on a local scale in the German Wadden Sea. Inclusion of parameters such as nest success and breeding success in the TMAP would enable a much more powerful assessment of the processes causing population changes of breeding birds, and consequently provide a better basis for management measures. It would also quantify the impact of, for example, predation, which seems to be a new problem, but where sound data regarding its impact is lacking.

A large-scale approach would also be helpful in studies of the response of breeding birds to changes in, for example, salt marsh management, which so far have been carried out at only a few sites, and sometimes show contradictory results. Therefore, we would encourage further studies which would bring together breeding bird surveys, data on reproduction and survival and data on habitat changes. Their results are indispensable to understanding the processes at work, and would enable a scientific assessment of management policies taken. Also, predictions can be made of the impact of newly developed management measures.

12.1.8 Recommendations

Considering the trends in breeding bird numbers highlighted above, recommendations for future management focus at four aspects:

- prevent disturbance of beach-breeding birds (kentish plover and great ringed plover) at sites where conflicts with outdoor recreation arise. As a first step in this process an inventory of breeding sites and potential threats should be carried out;
- prevent human limitations in food stocks for bivalve-specialists such as common eider and oystercatcher and review all shellfish fisheries in the Wadden Sea with regard to the target of a favorable food availability, possibly assessed by scientific research;
- prevent the risk of predation by mammalian predators, especially on islands where improvement of existing dams to the mainland (as proposed for Hallig Oland in Schleswig-Holstein) will facilitate predators expanding their range and thus increase predation rates;
- improve knowledge about reproduction rates, mortality rates and habitat requirements, in order to better evaluate management measures and assess backgrounds for the trends observed. This is preferably to be achieved within the TMAP framework, and should include at least parameters for reproductive success.

Furthermore, it is recommended that a specific instrument be established (e.g. 'List of Priority Species') identifying those typical Wadden Sea breeding birds that are under serious risk. Previously, a Red List of Wadden Sea Birds was issued in 1996 (Rasmussen *et al.*, 1996). This 'Trilateral Red List of Birds in the Wadden Sea Area' has been an important result of the trilateral monitoring as well as an important step for the evaluation of nature conservation policies in the Wadden Sea. However, it has not achieved much authority and to some extent it has been overruled by the EC Birds and Habitats Directives. It should be noted, however, that some typical Wadden Sea bird species (such as common eider and ruff), face problems and are not well covered by these EC Directives, and so a further instrument might still be useful. We therefore propose that a 'List of Priority Species' be made which should be assessed and updated, for example, every five years to assist evaluation of the trilateral targets and recommendations.

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12.2 Migratory Birds



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Shelducks on Trischen
(Photo: M. Stock)

12.2.1 Introduction

The Wadden Sea is of outstanding international importance as a staging, moulting and wintering area for at least 52 populations of 41 migratory waterbird species that use the East Atlantic flyway and originate from breeding populations as far away as northern Siberia or Northeast Canada (Meltofte *et al.*, 1994). Numbers of 44 populations of 34 species occurring in the Wadden Sea are so high that this area can be considered their indispensable and main stepping stone during migration, or their primary wintering or moulting habitat. Nearly the entire population of the dark-bellied brent goose *Branta b. bernicla* and the entire North-European population of dunlin *Calidris alpina* use the Wadden Sea during some periods of their annual cycle. For an additional seven species more than 50% of the total population uses the Wadden Sea, and a further 14 species are present with more than 10% of their flyway population. These figures may in fact be much higher when considering turnover (see Meltofte *et al.*, 1994 and below). In addition, the Wadden Sea and the coastal zone of the adjacent North Sea are used by high numbers of moulting and feeding common eider *Somateria mollissima* and support the entire Northwest-European population of common shelduck *Tadorna tadorna* during moult in summer (Blew *et al.*, 2005).

In recent decades, the amount and quality of data on migratory waterbirds has increased considerably. Being part of the International Water-

bird Census of Wetlands International, surveys used to focus mainly on wintering numbers and distribution (Meltofte *et al.*, 1994). The current Joint Monitoring of Migratory Birds (JMMB), carried out in the framework of TMAP, consists of two synchronous (complete) counts each year (in some countries more than two) and bi-monthly counts during spring tide at numerous sample sites (Rösner, 1993). All these counts are carried out during high tide, when most birds congregate at high tide roosts, within reach of observers (see Koffijberg *et al.*, 2003 and Blew *et al.*, 2005 for details). These surveys allow assessments of numbers, distribution, phenology and trends. Knowledge of trends has much improved over the past years, since not only wintering numbers (which are often small and fluctuate according to the weather) but also the more important migration periods can be fully taken into consideration. Therefore, for the first time, overall trends of the most important species can be calculated for the entire Wadden Sea including all months of the year.

This chapter summarizes the results of the latest review of migratory bird numbers in 1992 – 2000 and provides information on trends during this time period. Maximum bird numbers given are 'estimated numbers' which take missing counts into account by calculating estimates for areas which were not covered during a count ('imputing', see Blew *et al.*, 2005 for details). In addition, particular assessments with regard to the ecolog-

ical targets for migratory waterbirds will be given (see chapter 12.2.4). Some of this data has been retrieved from projects which were conducted as part of the Wadden Sea Plan, e.g. a review of sea-duck moulting sites (Hennig and Eskildsen, 2001), an overview of goose management schemes (Laursen, 2002) and an inventory of roosting sites (Koffijberg *et al.*, 2003).

The ecological targets for migratory birds, formulated in the Wadden Sea Plan are:

Targets

Favorable conditions for breeding and migratory birds:

- favorable food availability
- natural breeding success *
- sufficiently large undisturbed roosting and moulting areas
- natural flight distances

* mainly relevant for breeding birds

Table 12.2.1:

Maximum numbers in the Wadden Sea per species during 1980–1991 (Meltofte *et al.*, 1994) and during 1992–2000 (Blew *et al.*, 2005). Population estimates and ranges are taken from Wetlands International (2002). 'winter' behind a scientific name indicates a population that winters in the Wadden Sea area; species included in Annex I of the EC Birds Directive are marked with an asterisk (*); species which are also typical breeding birds in the Wadden Sea, are printed in bold.

Species		1980–1991	1992–2000	Population Estimate	Population Range
		Maximum number in the Wadden Sea estimated			
Great cormorant	<i>Phalacrocorax carbo sinensis</i>	4,660	17,200	275,000–340,000	N, Central Europe
Eurasian spoonbill *	<i>Platalea leucorodia</i>	262	1,090	9,950	East Atlantic
Barnacle goose *	<i>Branta leucopsis</i>	103,000	278,000	360,000	N Russia, E Baltic (breeding)
Dark-bellied brent goose	<i>Branta b. bernicla</i>	220,000	255,000	215,000	W Siberian (breeding)
Common shelduck	<i>Tadorna tadorna</i>	254,000	219,000	300,000	NW Europe (breeding)
Eurasian wigeon	<i>Anas penelope</i>	320,000	333,000	1,500,000	NW Europe (non-breeding)
Common teal	<i>Anas crecca</i>	56,600	38,700	400,000	NW Europe (non-breeding)
Mallard	<i>Anas platyrhynchos</i>	165,000	170,000	4,500,000	NW Europe (non-breeding)
Northern pintail	<i>Anas acuta</i>	16,200	15,900	60,000	NW Europe (non-breeding)
Northern shoveler	<i>Anas clypeata</i>	3,960	6,030	40,000	NW & C Europe (non-breeding)
Common eider	<i>Somateria mollissima</i>	309,000 ¹	311,000 ¹	850,000–1,200,000	Baltic, Wadden Sea
Eurasian oystercatcher	<i>Haematopus ostralegus</i>	739,000	582,000	1,020,000	Europe, NW Africa
Pied avocet *	<i>Recurvirostra avosetta</i>	44,600	46,400	73,000	W Europe (breeding)
Great ringed plover	<i>Charadrius h. hiaticula</i> winter			73,000	Europe, N Africa (non-breeding)
	<i>Charadrius h. tundrae</i>	14,100	32,900	145,000–280,000	SW Asia, E&S Africa (non-breeding)
	<i>Charadrius h. psammmodroma</i>			190,000	W&S Africa (non-breeding)
Kentish plover *	<i>Charadrius alexandrinus</i>	812	704	62,000–70,000	E Atlantic, W Mediterranean
Eurasian golden plover *	<i>Pluvialis apricaria</i>	168,000	153,000	69,000	NW Europe (non-breeding)
	<i>Pluvialis apricaria</i> winter			930,000	W & S Continental Europe, NW Africa (non-breeding)
Grey plover	<i>Pluvialis squatarola</i>	140,000	106,000	247,000	E Atlantic (non-breeding)
Northern lapwing	<i>Vanellus vanellus</i>	132,000	113,000	2,800,000–4,000,000	Europe (breeding)
Red knot	<i>Calidris c. canutus</i>	433,000	339,000	340,000	C Siberia (breeding)
	<i>Calidris c. islandica</i> winter			450,000	Greenland, High Arctic Canada (breeding)
Sanderling	<i>Calidris alba</i>	20,200	20,300	123,000	E Atlantic, W&S Africa (non-breeding)
Curlew sandpiper	<i>Calidris ferruginea</i>	6,680	10,700	740,000	W Africa (non-breeding)
Dunlin	<i>Calidris alpina</i>			1,330,000	W Europe (non-breeding)
	<i>Calidris alpina schinzii</i> * ²	1,200,000	1,380,000	3,600–4,700	Baltic (breeding)
Ruff *	<i>Philomachus pugnax</i>	19,800	5,250	2,200,000	W Africa (non-breeding)
Bar-tailed godwit *	<i>Limosa l. lapponica</i> winter	341,000	273,000	120,000	Coastal W Europe, NW Africa (non-breeding)
	<i>Limosa l. taymyrensis</i>			520,000	Coastal W & SW Africa (non-breeding)
Whimbrel	<i>Numenius phaeopus</i>	1,330	2,120	160,000–300,000	NE Europe (breeding)
Eurasian curlew	<i>Numenius arquata</i>	227,000	279,000	420,000	W, Central & N Europe (breeding)
Spotted redshank	<i>Tringa erythropus</i>	15,200	18,800	77,000–131,000	Europe (breeding)
Common redshank	<i>Tringa t. robusta</i> winter			64,500	Iceland & Faeroes (breeding)
	<i>Tringa t. totanus</i>	59,600	65,100	250,000	E Atlantic (non-breeding)
Common greenshank	<i>Tringa nebularia</i>	15,000	18,800	234,000–395,000	Europe (breeding)
Ruddy turnstone	<i>Arenaria interpres</i> winter			94,000	NE Canada, Greenland (breeding)
	<i>Arenaria interpres</i>	7,020	6,960	46,000–119,000	Fennoscandia, NW Russia (breeding)
Common black-headed gull	<i>Larus ridibundus</i>	242,000	499,000	5,600,000–7,300,000	N & C Europe (breeding)
Common gull	<i>Larus canus</i>	103,000	198,000	1,300,000–2,100,000	Europe, N Africa (non-breeding)
Herring gull	<i>Larus a. argentatus</i> winter			1,100,000–1,500,000	N & W Europe (non-breeding)
	<i>Larus a. argentatus</i>	328,000	243,000	1,090,000	NW Europe S to N Iberia (non-breeding)
Great black-backed gull	<i>Larus marinus</i>	15,400	16,300	420,000–510,000	NE Atlantic

¹ Numbers of common eider are derived from extra aerial counts.

² Only the population *Calidris alpina schinzii* is included in the Annex I of the EC Birds Directive.

12.2.2 Quality Status Report 1999

During assessments for the 1999 QSR, numbers of great cormorant *Phalacrocorax carbo*, dark-bellied brent goose, barnacle goose *Branta leucopsis*, Eurasian wigeon *Anas penelope*, Eurasian oystercatcher *Haematopus ostralegus*, grey plover *Pluvialis squatarola* and several gull species all showed thriving populations and long-term increases. For many species, this was attributed to improved protection measures in the past decades (e.g. a hunting ban on dark-bellied brent goose) and improved food availability through eutrophication, intensification of agriculture and fisheries (*i.e.* discards). Problems were especially noted in species feeding on blue mussels *Mytilus edulis*. In Denmark, distribution and numbers of both the common eider and the Eurasian oystercatcher were affected by shellfish-fisheries (Laursen and Frikke, 1987; Laursen *et al.*, 1997; CWSS, 2002). Both species experienced declines (along with mass-mortality in severe winters) also in the Dutch Wadden Sea. Here, mussel (and also cockle *Cerastoderma edule*) fisheries in combination with occurrence of severe winters were the main cause for declines in common eider and the Eurasian oystercatcher (Camphuysen *et al.*, 1996, 2002). Another matter of concern was the changed management of salt marshes (from livestock-grazed towards natural succession, possibly affecting food availability of herbivores, *e.g.* geese), the unsatisfactory management of human disturbance at roosting sites and the development of wind farms in the coastal zone behind the sea dike (a threat to migrating birds, disturbing feeding sites and high tide roosts). These topics will be reviewed in more detail in chapter 12.2.4.

12.2.3 Numbers and trends in 1992–2000

12.2.3.1 Maximum numbers and international importance

A total of 34 species with 44 distinct geographical populations have to be regarded as typical migratory and wintering birds of the Wadden Sea occurring in high numbers (Table 12.2.1; Blew *et al.*, 2005). Adding up the maximum numbers for each species results in some 6.1 million waterbirds present in the Wadden Sea. Besides the great cormorant and Eurasian spoonbill *Platalea leucorodia*, this comprises 1.66 million ducks and geese, 3.36 million waders and 955,000 gulls. These figures, however, do not take into account turnover. When considering the continuous arrival and departure of many migratory birds, many more individuals utilize the Wadden Sea: 10–12 million as estimated by Meltofte *et al.* (1994). Most species reach highest numbers during autumn migration from July onwards; wader numbers are almost as high during spring, whereas ducks and geese winter in high numbers. Only gulls reach considerable numbers in summer. The share of the international population that regularly uses the Wadden Sea gives an impression of its importance for the conservation of the total flyway population. All but two species fulfill the 1%-criterion of international importance according to the Ramsar Convention, more than 10% of 23 of the considered populations utilize the Wadden Sea (Figure 12.2.1).

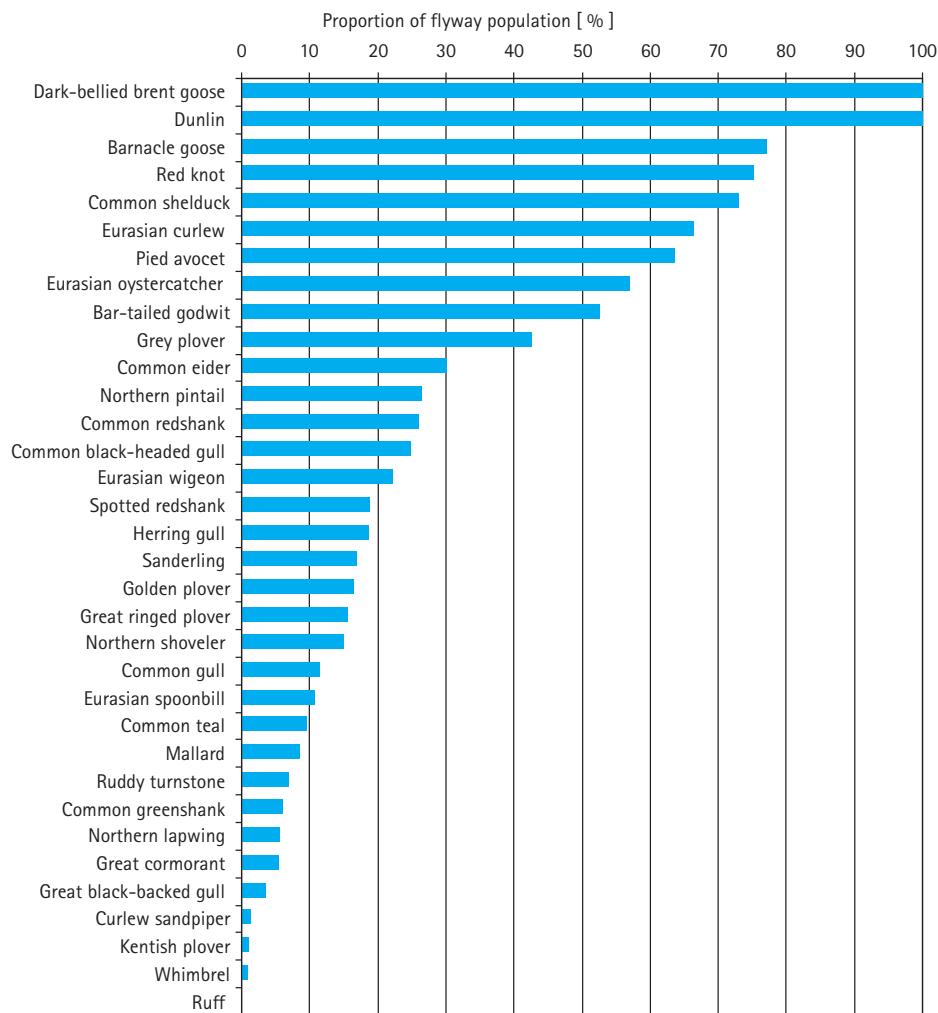
12.2.3.2 Calculation of trends

Trends provide important information concerning the status of the Wadden Sea for waterbird popu-



Barnacle geese foraging in Ballum Enge, Denmark.
(Photo: J. Frikke)

Figure 12.2.1:
Maximum estimated numbers 1992–2000 (Blew et al., 2005) given as proportion of flyway populations (Wetlands International, 2002).



lations. Calculations of trends were made for winter (January) and for all months (overall trends). Winter trends are based on the international synchronous counts in January and are also used for international comparisons with regard to the relevant flyway populations (Wetlands International, 2002). Only a few species, however, winter in considerable numbers in the area. Most species use the Wadden Sea as a staging habitat. For these species, overall trends, which include peak migration periods in spring and autumn, are a more reliable parameter for detecting changes in numbers using the Wadden Sea since they take into account all important stages of the annual cycle (Table 12.2.2).

12.2.3.3 Winter trends

During January 1980–2000, peak numbers of 25 species (involving varying proportions of their geographical populations) exceeded 1,000 individuals and allowed a proper trend estimate. Only few species showed pronounced trends, such as grey plover, Eurasian wigeon, great cormorant, barna-

cle goose, common eider and common gull *Larus canus* (Table 12.2.2). For great cormorant and barnacle goose, this development reflects the expansion of the total flyway population; for Eurasian wigeon and grey plover, this reflects an increase in wintering numbers of these species in Northwest-Europe (Wetlands International, 2002). Most species, however, experience fluctuations without showing a trend. The lack of clear trends in winter is mainly caused by the alternating impact of severe and mild winters. This pattern leads to a long-term increase of most species during 1980–2000, but a short-term decrease during 1992–2000 (giving an overall fluctuating trend). Cold spells and (partial) ice-cover occurred, for example, in January 1982, 1985, 1986, 1987, 1996 and 1997. In these years, species such as Eurasian wigeon, mallard *Anas platyrhynchos*, northern pintail *Anas acuta*, Eurasian oystercatcher, and Eurasian curlew *Numenius arquata* declined in the Wadden Sea and subsequently showed high numbers in France (Deceuninck and Maheo, 2000), suggesting southbound displacements of birds that usu-

Table 12.2.2:

Trend estimates of migratory birds in the Wadden Sea with the importance of season and indication of food preference, listed according to 'overall trend'.

* A = autumn, W = winter, S = spring, xx = season is important, x = season is less important, - = season is unimportant for trend estimation;

** ++/-- substantial increase/decrease (> 20% in 10 years); +/- increase/decrease (< 20% in 10 years); O stable; F fluctuating; n.s. trend estimate not significant; *** Wetlands International (2002).

Species	Wintering grounds	Breeding grounds	Food preference (in Wadden Sea)	Importance of season*			Overall trend** 1992 to 2000	January trend** 1980 to 2000	Flyway population trend*** most recent years
				A	W	S			
Ruddy turnstone	trop. Afr. / W Eur	arctic	benthos	xx	x	xx	--	+ (n.s.)	+
Common redshank	trop. Afr. / W Eur	non-arctic	benthos	xx	x	x	--	F	- / 0 / +
Red knot	trop. Afr. / W Eur	arctic	benthos-shellfish	xx	x	xx	--	++ (n.s.)	-
Eurasian oystercatcher	W Eur	non-arctic	benthos-shellfish	xx	xx	x	--	F	-
Grey plover	trop. Afr. / W Eur	arctic	benthos-worm	xx	x	xx	--	++	+
Dunlin	W Eur / Med.	arctic	benthos-worm	xx	x	xx	--	++ (n.s.)	0
Curlew sandpiper	trop. Afr.	arctic	benthos-worm	xx	-	-	--		+
Pied avocet	trop. Afr. / Med.	non-arctic	benthos-worm	xx	-	x	--		0
Mallard	W Eur	non-arctic	herbivore/benthos	x	xx	-	--	+ (n.s.)	-
Dark-bellied brent goose	W Eur	arctic	herbivore	x	x	xx	--	+ (n.s.)	-
Eurasian wigeon	W Eur	non-arctic	herbivore	xx	xx	x	--	++	+ ?
Spotted redshank	trop. Afr.	arctic	benthos	xx	-	xx	-		0
Eurasian curlew	W Eur	non-arctic	benthos	xx	xx	x	-	++ (n.s.)	+ / 0
Common greenshank	trop. Afr.	non-arctic	benthos	xx	-	x	-		0
Bar-tailed godwit	trop. Afr. / W Eur	arctic	benthos-worm	x	x	xx	-	++ (n.s.)	- / 0
Herring gull	W Eur	non-arctic	benthos-shellfish/generalist	xx	xx	x	--(n.s.)	++ (n.s.)	-
Sanderling	trop. Afr. / W Eur	arctic	benthos-worm	x	x	xx	-(n.s.)	++ (n.s.)	0 / +
Golden plover	Med. / W Eur	non-arctic	benthos-worm/terrestrial	xx	x	xx	-(n.s.)	++ (n.s.)	0 / +
Northern lapwing	Med. / W Eur	non-arctic	benthos-worm/terrestrial	xx	-	x	-(n.s.)	++ (n.s.)	-
G. black-backed gull	W Eur	non-arctic	generalist	xx	xx	x	-(n.s.)	++	0
Northern pintail	Med. / W Eur	non-arctic	herbivore/benthos	xx	x	x	-(n.s.)	+ (n.s.)	-
Great cormorant	Med. / W Eur	non-arctic	fish	xx	-	-	++	++	+
Barnacle goose	W Eur	arctic	herbivore	xx	x	xx	++	++	+
Eurasian spoonbill	Trop. Afr. / Med.	non-arctic	benthos-shrimp	xx	-	-	+		+
Common shelduck	W Eur	non-arctic	benthos	xx	xx	-	+ (n.s.)	F	0
Ringed plover	trop. Afr.	arctic	benthos-worm	xx	-	xx	+ (n.s.)		+
Whimbrel	trop. Afr.	arctic	benthos-crustaceae/frugivore	xx	-	-	F		+ / 0
Common eider	W Eur	non-arctic	benthos-shellfish	-	xx	-	F	++	-
Ruff	trop. Afr.	arctic	benthos-worm	xx	-	xx	F		-
Kentish plover	trop. Afr. / Med.	non-arctic	benthos-worm	xx	-	x	F		-
C. black-headed gull	W Eur	non-arctic	generalist	xx	x	x	F	+ (n.s.)	+
Common gull	WS	non-arctic	generalist	xx	x	x	F	++	-
Common teal	Med. / W Eur	non-arctic	herbivore/benthos	xx	x	x	F	F	+
Northern shoveler	Med. / W Eur	non-arctic	herbivore / benthos / plancton	xx	x	x	F	+ (n.s.)	+

ally winter in the Wadden Sea. Considering the expectation of more frequently occurring milder winters in the longer term (cf. chapter 3), wintering numbers and distribution over the Wadden Sea might change for some species in future. Such a change has already been reported for wintering wader populations in the UK, which have partly switched from the west to the east coast (Austin *et al.*, 2003).

12.2.3.4 Overall trends

During autumn and spring, when the Wadden Sea serves as a migration, moulting, staging and roosting habitat, the impact of weather is not as great as during winter, allowing a more robust trend assessment. Looking at the 34 species considered, the alarming fact arises that 15 species (44% out

of 34 species considered) experienced a significant decrease in the 1990s (Table 12.2.2). Among these are species of which more than 50% of the total flyway population migrates through, or stays within the Wadden Sea (cf. Figure 12.2.1), such as red knot *Calidris canutus*, Eurasian oystercatcher, dunlin, pied avocet *Recurvirostra avosetta*, dark-bellied brent goose, Eurasian wigeon, Eurasian curlew *Numenius arquata* and bar-tailed godwit *Limosa lapponica*. Another seven species (21%) show a decline as well, although not a statistically significant one. Many of the declining species have in common that they are long-distance migrants and their life strategy includes periods of fast refueling of body reserves in the Wadden Sea, en route to their high arctic breeding areas or African wintering sites. Since the declining numbers

for these species have not been confirmed elsewhere in Europe (e.g. UK: Austin *et al.*, 2003; France: Deceunick and Maheo, 2000), the underlying causes for the downward trends are to be sought in the Wadden Sea (Davidson, 2003). This is also supported by declining breeding populations in resident species such as the Eurasian oystercatcher (*cf.* Table 12.1.1 in chapter 12.1). At a local scale, declines in breeding populations have been also noticed recently in pied avocet and herring gull (Dijksen *et al.*, in prep.), of which major parts of the population stay in the Wadden Sea after the breeding season.

The causes for the observed population declines are not known in detail for all species, and cannot be assessed by monitoring alone. At least for dark-bellied brent goose, there is a clear relationship with poor breeding seasons (see section 'Favorable food availability' below). For several benthos-eaters (common eider, Eurasian oystercatcher) there is evidence that food availability has deteriorated in the past decades (see below).

Compared to the many declining species, rather few species show significant upward overall trends. For the great cormorant, Eurasian spoonbill and barnacle goose, the entire Northwest-European populations have increased in the past decade (Wetlands International, 2002). For many other species (e.g. whimbrel *Numenius phaeopus*, ruff *Philomachus pugnax*) only fluctuating trends could be observed, mainly because these species utilize the Wadden Sea in rather low numbers (*cf.* Figure 12.2.1).

12.2.4 Target evaluation

12.2.4.1 Sufficiently large undisturbed roosting areas

Since most of the waterbirds in the Wadden Sea gather at specific roosts during high tide, the safeguarding of these high tide roosts is an issue for the conservation and protection of birds in the Wadden Sea. In order to assess possible conflicts between nature and human interests, the current status of roosts (bird numbers, protection regimes and anthropogenic disturbance) was recently reviewed (Koffijberg *et al.*, 2003). In general terms, numbers and species observed at a high tide roost in a dynamic area like the Wadden Sea are influenced by many factors, including actual water tables, distance to the nearest favorable feeding areas, preferred roosting habitat, site-tenacity and social status of the birds. As a result, species often use a network of roosting sites. For mobile species such as red knot, this might within a short run of tidal cycles even cover an area of 800 km²,

whereas others, such as dunlin, are extremely faithful to certain feeding areas and high tide roosts. The largest roosting sites are located where large intertidal mudflats occur at close range and low levels (or absence) of human disturbance prevail. This combination is found especially on some remote and uninhabited islands, such as Süderoogsand and Trischen (Schleswig-Holstein), Scharhörn (Hamburg), Memmert and Mellum (Niedersachsen), Griend and Richel (both The Netherlands) (Figure 12.2.2).

12.2.4.2 Disturbance and protection of roosting sites

The level of anthropogenic disturbance is one of the most important factors regulating bird numbers at high tide roosts, and often puts an extra constraint on the birds' narrow energetic balance and tight time schedule for migration. Case studies in several parts of the Wadden Sea have pointed out that recreational activities are among the most frequently observed sources of anthropogenic disturbance. This is confirmed by the recent inventory by Koffijberg *et al.* (2003), which points out that 29% to 42% of all roosting sites are subject to an estimated moderate to heavy recreational pressure (Figure 12.2.3). Moreover, data on phenology show that the seasonal occurrence of some species is affected by recreation pressure and birds tend to avoid roosts visited by many people in the summer holiday season. As this holiday season is extending to spring and autumn, it is expected that more recreational pressure will arise in near future, especially when regarding the timing of migration of long-distance migrants, for which important numbers use the Wadden Sea as a stop-over in late spring (May) and summer (July-September).

Another, more local source of disturbance is hunting, which is observed at many sites (up to 33% of all sites in Denmark when regarding moderate to heavy hunting pressure). Laursen (2005) has demonstrated the severe impact of hunting in the Danish Wadden Sea. For the Eurasian curlew, it is concluded that the gradual hunting restrictions and the final hunting ban in Denmark in 1992–94 resulted in a population increase in this species in the entire Wadden Sea (at least during winter) in the mid 1990s. Although the hunting of migratory waterbirds was gradually phased out in the entire Wadden Sea during the 1990s, hunting small mammals such as hares *Lepus europaeus* and rabbits *Oryctolagus cuniculus* is still common practice and also occurs on salt marshes close to important high tide roosts, thus causing disturbance.

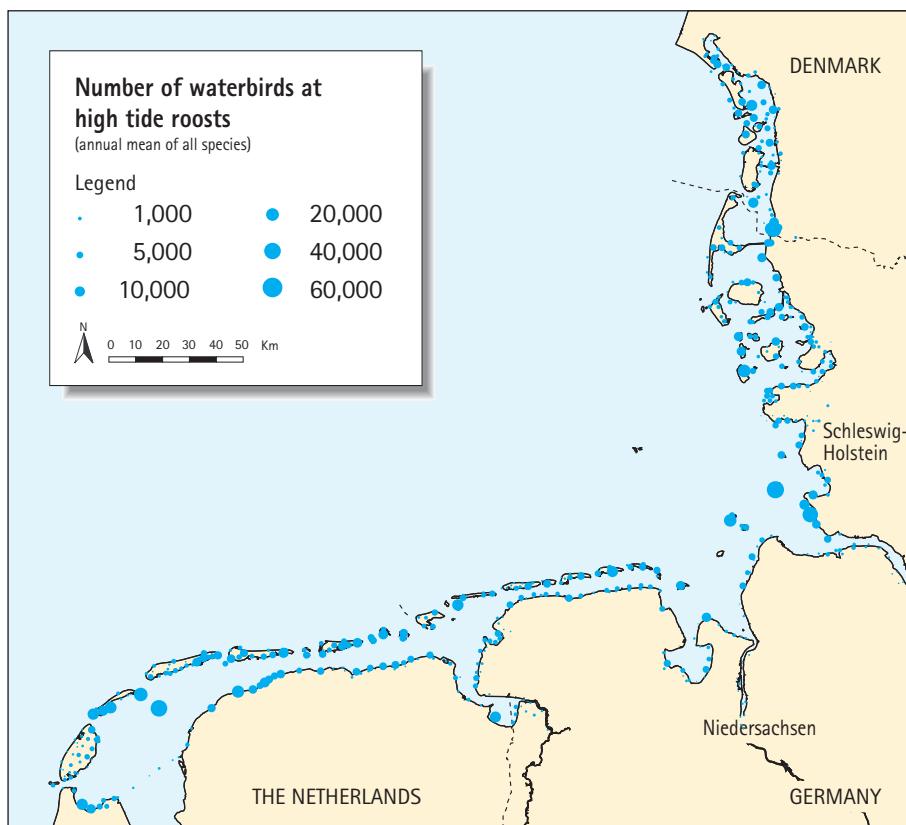


Figure 12.2.2:
Overview of high tide roosts in the Wadden Sea, expressed by the sum of annual means of all relevant species. Large roosts occur in areas close to large intertidal flats and at sites with low anthropogenic disturbance (Koffijberg et al., 2003).

Additional sources of potential anthropogenic disturbance, also at a limited number of sites, are civil air traffic, military training activities and inland wind farms. The latter have been reported to affect inland roosting behavior close to the seawall, especially for coastal waders and geese.

Regarding protection regimes, most countries have more than 80% of their high tide roosts (supporting for most species >90% of the birds observed) within areas that have been designated as a Special Protection Area (SPA) under the Birds Directive and/or as a Ramsar site. The majority of sites are therefore subject to regulations addressing bird conservation targets. In The Netherlands and Niedersachsen, this figure is somewhat lower, since both countries have a large proportion of inland agricultural areas among their roosting sites which are subject to limited special protection measures. Only in Niedersachsen and in Denmark have some of these agricultural areas been included within SPAs, whereas in The Netherlands agricul-

tural areas behind the seawall were not taken into account at all in the last SPA designation of 2000. Especially species such as the barnacle and dark-bellied brent goose, Eurasian golden plover *Pluvialis apricaria* and the Eurasian curlew are known to utilize inland roosts in large numbers. Moreover, inland sites are part of the network of existing roosting sites and increase in importance for all species during high water tables when regular coastal high tide roosts are flooded.

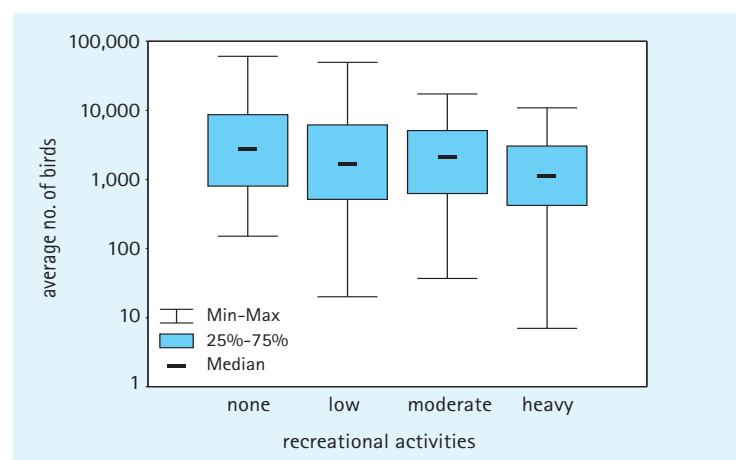
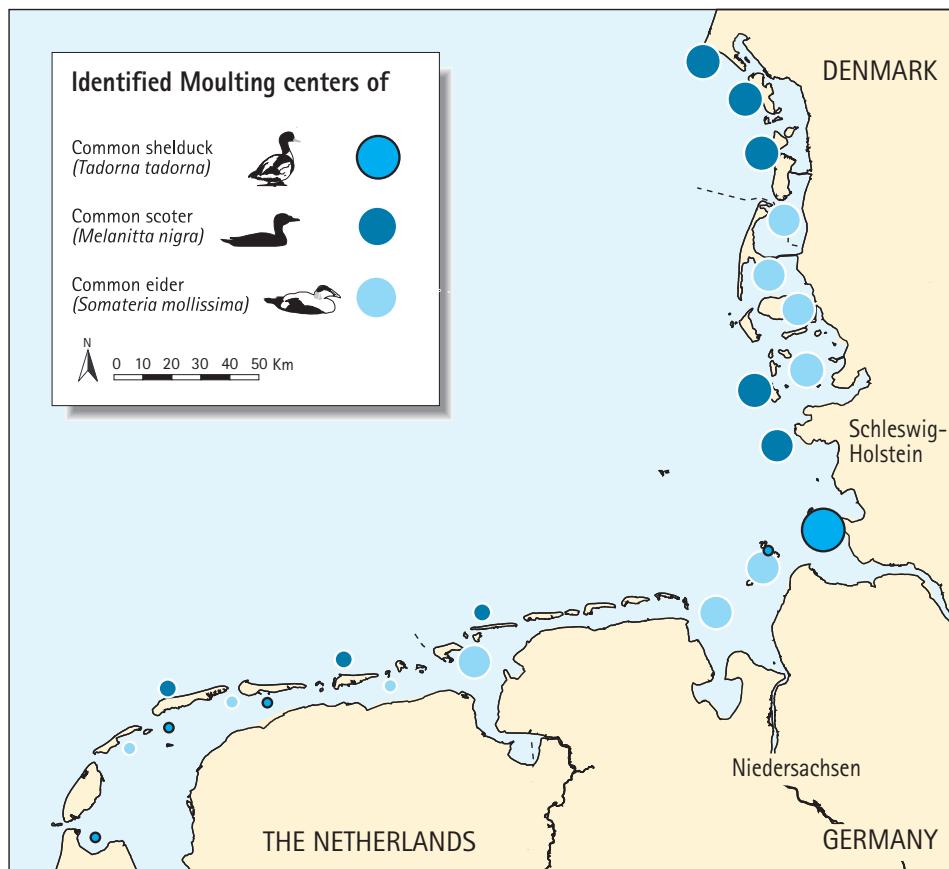


Figure 12.2.3:
Bird numbers at high tide roosts in relation to different levels of recreational activities. Although variation is large there is a significant impact of recreational pressure on the number of roosting birds (Koffijberg et al., 2003).

Figure 12.2.4:
Moult distribution of common shelduck, common scoter and common eider (Kempf, 2001; Henning unpubl.; Scheiffarth and Frank, 2005). Size of circles according to the importance of the moult site for each species.



12.2.4.3 Sufficiently large undisturbed moult areas

Several bird species, particularly waterbirds such as grebes, swans, geese and ducks, moult their flight feathers simultaneously during a period of several weeks in summer during which they cannot fly. In this period, they are extremely vulnerable to predators and anthropogenic disturbance and often concentrate in remote areas. The Wadden Sea and the adjacent North Sea area support internationally important moult concentrations of common shelduck, common eider and common scoter *Melanitta nigra* (Figure 12.2.4). Thus, the Wadden Sea countries have a great responsibility for the protection of these species. Moult behavior and phenology differs among the three species and management thus requires a species-specific approach.

Common shelduck moult from late June to early September in the vicinity of undisturbed and extended mudflats. The most important moult sites for shelduck have recently shifted and are now almost exclusively situated within the southern Schleswig-Holstein Wadden Sea (Kempf, 1999, 2001) (Figure 12.2.4). Up to 2002, a large proportion of the entire Northwest-European shelduck population, regularly exceeding 200,000 individ-

uals, synchronously concentrated at this moult site during late July and August. Smaller numbers (10–20,000 birds) moult in The Netherlands (Leopold, 2003), although reliable information is lacking here due to the absence of offshore counts in summer.

Concentrations of moult common eider are found from July until the end of August, particularly in large areas with very low disturbance levels, rich shellfish resources and roosting sites on sand banks. Their moult areas are less concentrated compared to those for scoters and shelducks. Moult populations in the German and the Danish Wadden Sea involved 170,000–230,000 individuals in the last two decades. Numbers have decreased from 1989 onwards (Desholm *et al.*, 2002), with a steep decline since 1994 in the major moult area, the North-Friesian Wadden Sea (Scheiffarth and Frank, 2005). Other concentrations are found in remote areas such as the Randzel area near Borkum, Niedersachsen. The East-Friesian Wadden Sea between Juist and Wangerooge is not used for moult, although in some years favorable feeding conditions seem to exist here. This area is intensively used for tourist activities and thus might be exposed to high levels of disturbance. In Denmark, a negative rela-



Common eiders
(Photo: G. Nehls).

tionship was found between the number of moulting eiders and the number of boats at sea (Laursen *et al.*, 1997) and in the Königshafen area on the island of Sylt it could be directly shown that wind surfing activities drove moulting eiders away from a rich food source (Ketzenberg, 1993). Hardly any recent information on Dutch moulting eider numbers is available. In the 1980s, this part of the Wadden Sea supported about 40,000 birds (Swennen *et al.*, 1989). Recent information is sporadic, but suggests some smaller concentrations.

Common scoters show the longest moulting period (June to October) since immature birds, males and females have consecutive moulting schedules. Compared to the other two species, moulting behavior is less well-known, as they prefer offshore feeding sites and usually occur highly dispersed over the sea surface, making counts difficult. With regard to food, scoters seem to be highly opportunistic. While for The Netherlands, scoters are considered highly dependent on *Spisula* as an important food resource (Leopold *et al.*, 1995; Leopold and Van den Land, 1996), they seem to focus on other food resources in Germany and Denmark. Due to the dispersed flocking behavior, common scoters are very susceptible to any source of disturbance; with approaching ships for instance, a flight distance of about two km has been reported. The importance of the entire Wadden Sea for moulting scoters decreases from Denmark over Germany to The Netherlands. Moulting centers of common scoter in all three Wadden Sea countries have been identified (Hennig, unpubl.) and have recently been confirmed for the federal state of Schleswig-Holstein (Hennig and Eskildsen, 2001; Deppe, 2003) (Figure 12.2.4). However,

numbers of moulting scoters seem to be underestimated in Germany and The Netherlands, making proper assessments in those countries difficult.

12.2.4.4 Disturbance and protection of moulting sites

Sources of disturbance of the moulting flocks range from commercial fisheries to boat and air traffic and oil spills. Some of these activities are regulated in parts of the Wadden Sea. In Germany, the national parks established a zoning system regulating many uses. Together with additional mandatory and voluntary regulations with regard to boat traffic, this system regulates the spatial and temporal use of certain areas and involves commercial and non-commercial fishery, leisure activities such as sailing, motor-boating (including commercial tourist ships and their excursions), surfing and canoeing. The effectiveness of these measures is monitored within the TMAP ('migratory birds' and 'boats at sea'). Oil spills pose an immense potential threat during the entire year, but seem to affect common scoters more than the other seabird species (see also chapter 4.4). However, in 1998, some 11,400 eider and 3,700 scoter died due to the *Pallas* accident (Günther, 1998). If marine wind farms were to be constructed within the 12-mile-zone, this and the associated boat traffic and other indirect effects would potentially reduce the areas available for moulting shelducks, eiders and scoters. Special Protection Areas (SPAs) within and outside the Wadden Sea have recently been designated and offer additional protection with regard to marine wind farms and other sources of disturbance. This additional protection, however, is not satisfactory for all species.



Barnacle geese on the
Hamburger Hallig
(Photo: M. Stock).

12.2.4.5 Favorable food availability: goose grazing and salt marsh management

The Wadden Sea region is an important staging area for arctic geese. Especially in spring, a major proportion of the Russian-Baltic population of barnacle geese and the entire West-Siberian population of dark-bellied brent geese stay in the Wadden Sea to accumulate body reserves for spring migration and breeding (Ebbing et al., 1999; Ganter et al., 1999). Data from the trilateral goose counts in the Wadden Sea and a review of recent changes in staging habits of both species have been used to evaluate the overall population trend, habitat use, phenology and goose management (Koffijberg and Günther, 2005). Goose-directed management in the Wadden Sea countries was reviewed by Laursen (2002) as part of the Wadden Sea Plan. In recent decades, the numbers, distribution and phenology of geese in the Wadden Sea have experienced major changes:

Barnacle goose

- Due to the increase of the Russian-Baltic flyway population, numbers and feeding range in the Wadden Sea have expanded considerably, especially in spring and mainly along the mainland coast and at sites outside the Wadden Sea;
- In the 1990s, up to 85% of the flyway population was concentrated in the Wadden Sea (March); recently, the Wadden Sea has become less important for wintering birds, which switch increasingly to inland grasslands in Niedersachsen and The Netherlands;
- Along with the expansion in numbers and feeding sites, barnacle geese have prolonged

their stay in spring by 4–6 weeks and now leave around mid May;

- As a result of the delayed spring departure, the Wadden Sea has become increasingly important for accumulating body reserves for breeding, especially for Russian barnacle geese.

Dark-bellied brent goose

- Low reproduction rates have initiated a decline in the population of dark-bellied brent geese, resulting in lower numbers in the Wadden Sea;
- Despite this downward trend, the spring staging sites in the Wadden Sea still support about 85% of the flyway population, whereas in winter only a minor share of the flyway population (10%) winters in the area;
- Following the population decline in the Wadden Sea, an increased proportion of the geese are found in the core staging areas on the barrier islands in The Netherlands and on the Halligen in Schleswig-Holstein.

For both species, the overall changes in numbers, distribution and habitat utilization in the Wadden Sea seem to be mainly related to changes at population level. No evidence has been found that changes in feeding and staging conditions in the Wadden Sea itself have contributed to the decline or increase in either species, although feeding opportunities did change during the past decades with, for example, the abandoning of livestock grazing in large parts of the mainland salt marshes of Schleswig-Holstein and Niedersachsen. Bos et al. (in press) concluded that if all salt marshes were livestock-grazed, the number of dark-bellied brent geese supported in spring could be four times higher compared to a situation with no livestock grazing at all. However, Bos et al. showed

that many suitable sites were used less than expected from their vegetation composition and were thus available as alternative sites when conditions elsewhere deteriorated. Similar findings were produced by a monitoring program in Schleswig-Holstein. Although the geese re-distributed over the area, the maximum numbers and duration of staging has not changed since livestock-grazing was reduced (Stock and Hofeditz, 2000, 2002). However, the sharp decrease in numbers of dark-bellied brent geese along the mainland coast of Schleswig-Holstein and the earlier arrival of large numbers of barnacle geese in the Dutch Wadden Sea might be an expression of a re-distribution process on a larger scale which could be related to changes in salt marsh management in the eastern part of the Wadden Sea. Analysis of re-sightings of individually marked birds could bring further evidence with regard to changes in site-use. In addition, distribution could be a result of competition between both species.

12.2.4.6 Favorable food availability: benthic feeders and shellfish fisheries

The trilateral Wadden Sea monitoring in the past decade has revealed strong overall declines for species which depend on shellfish (notably bivalves such as blue mussels and cockles) in the intertidal area, for example, the Eurasian oystercatcher and red knot (cf. Table 12.2.2). In addition, the Baltic/Wadden Sea population of common eider experienced a strong decline during the 1990s (Desholm *et al.*, 2002) and winter numbers in the Wadden Sea dropped to a low in 2001/2002 (the overall Wadden Sea trend 1992–2000, however, is fluctuating). Numbers of herring gulls increased between 1980 and 1990, but have shown declines since then, both in breeders and non-breeders (cf. chapter 12.1).

Blue mussel fisheries occur in all sections of the Wadden Sea, with the largest culture lots and landings in The Netherlands and Schleswig-Holstein (CWSS, 2002). Cockle fisheries have been allowed only in The Netherlands and a few small areas in Denmark. In Denmark, mussel fisheries were discussed (and consequently restricted in the 1980s), after additional mortality had occurred among several waterbirds (Laursen and Frikke, 1987; Laursen *et al.*, 1997; CWSS, 2002; Kristensen and Laursen, in prep.). Because of the presumed impact of shellfish fisheries and the observed declines and mass-mortality in several bird species, a comprehensive evaluation of fishery effect and bird numbers was carried out in the Dutch Wadden Sea and Oosterschelde recently (Ens *et al.*, 2004). This study, called EVA II, was a follow-up

of previous assessments of a management regime of closed and open areas for cockle fisheries in the Dutch Wadden Sea, and an annual quota accounting for food reserves for waterbirds. However, these measures were unable to halt the observed declines in bird populations. The EVA II study aimed to unravel the links between activities of blue mussel and cockle fisheries and the observed bird numbers, in order to balance the interests of shellfish fisheries and nature conservation.

The EVA II project has demonstrated that a complex set of factors led to an unfavorable food situation for birds, and finally caused a decrease in numbers in species such as common eider, Eurasian oystercatcher, red knot and perhaps herring gull. For the common eider and Eurasian oystercatcher, this confirms the hypothesis of Scheiffarth and Frank (2005) that in the Wadden Sea there is a conflict between these species and fishery. They compared consumption of mussel and cockle stocks by the Eurasian oystercatcher, common eider and herring gull in the entire Wadden Sea with data on mussel and cockle landings (as an indicator of the food stock available to the birds), and found a negative correlation between mussel landings and the consumption by the common eider and Eurasian oystercatcher. The EVA II study revealed that in the Dutch Wadden Sea both species suffered losses due to low blue mussel stocks, since these had been removed by mussel fisheries in the beginning of the 1990s (Ens *et al.*, 2004; Leopold *et al.*, 2004a). Severe winters (also affecting oystercatcher numbers), lower reproduction rates of blue mussels and perhaps also increased storminess contributed to the deteriorating food stocks as well (Ens *et al.*, 2004). As a result, oystercatchers had to switch to cockle stocks, for which they had to compete with cockle fisheries (Rappoldt *et al.*, 2003).

Common eiders especially were faced with lower mussel and cockle stocks and were not able to compensate for this by, for example, switching to alternative food stocks (e.g. *Spisula subtruncata* banks in the coastal zone of the North Sea) as the energy profitability of alternative prey is lower (Nehls, 2001) and competition with shellfish-fisheries also occurs on *Spisula* banks (Camphuysen *et al.*, 2002; Ens and Kats, 2004). For herring gull, fishery may provide only part of the explanation for the lower numbers, especially since the breeding population of this species is known to have suffered competition with increased numbers of lesser black-backed gull and reduced access to waste dumps (see chapter 12.1), both of which have reduced reproductive output (and thus num-

'Geese days' on the Halligen
(Photo: H.-U. Rösner)



bers counted after the breeding season). For the red knot, it is assumed that the recent population decline is related to changes in sediment, caused by the mechanical fishing devices used by cockle fisheries, rendering this sediment unsuitable for settlement of bivalve spat for a number of years (Piersma and Koolhaas, 1997; Piersma *et al.*, 2001). The impact on macrozoobenthos by cockle fisheries, however, is not yet clearly understood. There are indications that ragworm *Nereis diversicolor* densities have increased as a result of cockle fisheries (Leopold *et al.*, 2004b; Kraan *et al.*, 2004), but it remains difficult to isolate these changes from long-term increasing trends in worms (see chapter 8.2).

12.2.4.7 Natural flight distances: the Eurasian curlew and hunting

While little information is available about flight distances in general, it has been demonstrated that flock size and different weather conditions (e.g. wind force, visibility) influence the flight distances of several waterbird species (Laursen *et al.*, 2005). For geese, Wille (2000) showed that areas with and without hunting have significant differences in flight distance and goose flocks in areas where hunting takes place were more likely to take off when disturbed. Similar findings have been published for other goose species (Madsen, 1985, 1988) and in a study on Eurasian curlew in the

Danish Wadden Sea (Laursen *et al.*, 2005). Here, it was also demonstrated that hunted species show longer flight distances from an approaching person than non-hunted species. A comparison of the Dutch and Danish Wadden Sea demonstrated that in the Danish Wadden Sea flight distances are 1.4–2 times longer for seven species of waders and gulls. This could imply that birds may have habituated to the far higher number of people walking along the beaches and on the intertidal flats in the Dutch Wadden Sea, but also (and more likely) the far greater hunting activity in the Danish Wadden Sea at the time of the study may have led to a longer flight distance in this area. Since the seven species included both hunted and non-hunted species, the results also indicate that hunting activity influences flight distance for both groups of birds. Thus, hunting in general, regardless of the species, has a clear impact on the distribution and feeding behavior of waterbirds. This is not only confined to hunters' activities, but birds also respond earlier to other sources of anthropogenic disturbance in areas where hunting occurs. Another example is the reduced flight distance of geese as a consequence of both limited hunting and a wise tourism management in specific areas (Mock *et al.*, 1998; Liebmann, 1999; Stock and Hofeditz, 2002; Rösner, 2003).

12.2.5 Conclusions

12.2.5.1 Trends in waterbird numbers

A review of trends of waterbirds utilizing the Wadden Sea reveals that 22 out of the 34 species considered experienced declines in 1992–2000, of which 15 are (statistically) significant (Table 12.2.2). This is an alarming development since the 1999 QSR. Moreover, similar declines in these species have not been observed elsewhere, suggesting the Wadden Sea is the main bottleneck in these birds' lifecycle (Davidson, 2003). Among the species showing significant decreases, there is a large proportion for which the Wadden Sea represents an indispensable stop-over to refuel body reserves on migration routes between (often African) wintering grounds and the high arctic breeding range, i.e. those species of which a large proportion of the population uses the Wadden Sea. The causes of the observed trends are not known in detail yet for all species concerned. Therefore, besides the measures proposed in the following chapters, more ecological research is needed to understand and reverse the negative trends detected by monitoring. Comparing trends in the different countries and relating them to differences in policy and management might be a fruitful first step forward

to understanding the causes behind the population changes, as between countries often different (and sometimes opposite) trends are found for the same species (Günther, 2003; van Roomen *et al.*, 2003, 2005), which might be related to differences in management between the Wadden Sea countries.

12.2.5.2 Sufficiently large undisturbed roosting areas

Despite the extensive national and international protection regimes now covering major parts of the Wadden Sea and the majority of roosting sites, the actual status regarding high tide roosts is not satisfactory (see also Koffijberg *et al.*, 2003), and has not made significant progress since the 1999 QSR. Potential conflicts relate especially to outdoor recreation and its disturbing impact. Some kinds of outdoor recreation already occur near a major part of the roosting sites (Figure 12.2.3) and tourism-related activities are reported to be expanding to late spring and early autumn, when many of the species for which declines have been observed recently stop over in the Wadden Sea to replenish body reserves. Hence, an increase of recreational pressure would be an extra constraint on these species.

Another aspect which deserves attention is the hunting of small mammals in the vicinity of roosting sites. Although major achievements have been made concerning phasing out hunting of migratory waterbirds in the Wadden Sea in the past decades and since the 1999 QSR, any hunting activity (either of birds or mammals) close to birds' roosting sites causes disturbance. Moreover, hunting affects natural flight distances, and increases the disturbing impact of other anthropogenic activities.

The impact of civil air traffic (including ultra-light aircraft), military training activities and wind farms on roosting sites should be assessed in more detail. Civil air traffic has been largely regulated by trilateral standards now and is decreasing in volume (see chapter 2.5), but severe disturbance is still reported from a number of roosting sites. Military training activities have been partly phased out since the 1999 QSR (e.g. Terschelling NL) and occur only at a few sites, but one of these (Vlienhors at Vlieland) ranks among the most important high tide roosts in the entire Wadden Sea, presenting a continued conflict situation.

The establishment of wind farms in the Wadden Sea Cooperation Area is currently largely regulated, but conflicts may arise, especially when planning wind farms in inland areas close to the seawall. These areas, which for some species are

important roosting sites, have not always been included within the boundaries of protected areas. Especially in the Dutch Wadden Sea, all important waterbird concentrations and roosting sites behind the seawall have not been taken into account with the designation of Natura 2000 areas (see Koffijberg *et al.*, 2003).

12.2.5.3 Sufficiently large undisturbed moulting areas

The Wadden Sea supports important concentrations of moulting common shelduck, common eider and common scoter. Since the 1999 QSR, the knowledge of the issue of undisturbed moulting sites has improved. The three species considered differ with respect to their moulting period, distribution and moulting behavior. The moulting sites for common shelduck, concentrated in one area in the southern Schleswig-Holstein Wadden Sea, are probably sufficiently protected under the current protection regimes (National Park law and mandatory regulations). Monitoring covers both numbers of shelduck and sources of disturbance. In The Netherlands, where large moulting flocks were known in the past and have been re-discovered recently (Leopold, 2003) more information is needed on present-day moulting shelduck. The moulting distribution of the common eider is well known in the German and Danish Wadden Sea. Again, no data is available from The Netherlands. Since the decrease in numbers in the North-Frisian part of the Wadden Sea coincided with an increase in adjacent areas, it is possible that there has been a shift from the northern moulting areas towards more western parts of the Wadden Sea, and this should be investigated. While some of the moulting sites are sufficiently undisturbed and protected by regulations, potential sites in the East-Frisian Wadden Sea between Juist and Wangerooge are not used and it is assumed that the disturbance level, especially from recreational activities, is too high.

For the common scoter, so far, no realistic estimate of the total moulting population in the Wadden Sea area exists. Recently, in Schleswig-Holstein and Niedersachsen, new offshore counts have been organized in order to collect data with regard to proposed marine wind farms. However, several open questions with regard to common scoter population biology, feeding and moulting behavior and spatial and temporal distribution patterns still exist. Scoters seem to be very susceptible to human disturbance by ships or planes. To propose 'moulting reserves' for scoters, it would be helpful to know their flight distances, which can only be evaluated by an experimental ap-

proach. This is also urgent in relation to the planning of marine wind farms plus the associated ship traffic, which can potentially affect the distribution and activity of common scoters at sea during the moulting season (e.g. Garthe and Hüppop, 2004). An evaluation of suggested protection regimes was recently conducted for the German Exclusive Economic Zone of the North Sea (Garthe, 2003). A further assessment with regard to undisturbed moulting sites within and outside the Wadden Sea is needed.

12.2.5.4 Favorable food availability for herbivores

Of the three true herbivore aquatic bird species in the Wadden Sea, the dark-bellied brent goose and Eurasian wigeon are decreasing, and the barnacle goose is increasing. For none of these species, however, does food seem to be the sole or even the main factor causing these trends. With regard to the changes in goose populations, salt marsh management and the availability of alternative feeding sites has been an issue of discussion, for example, in the Leybucht in Niedersachsen (1999 QSR; Bergmann and Borbach-Jaene, 2001; Lutz *et al.*, 2003). A debate exists as to whether salt marshes should be managed in such a way that they can support maximum numbers of geese in order to reduce feeding in agricultural areas. However, when considering the high goose numbers and the naturally lower quality and quantity of food on salt marshes in autumn and winter (as compared to fertilized grassland), such a management scenario – working long-term against sharp gradients of habitat quality – would not solve the conflict between farmers and goose grazing since, at least in winter, fertilized grassland will remain the more attractive food resource. Moreover, tri-lateral targets concerning salt marsh management, which are also in line with the EC Habitats Directive, do not recommend such a species directed management, but aim to both increase the area of natural salt marshes, and provide favorable conditions for (all) migratory and breeding birds. Since both barnacle and dark-bellied brent geese depend on the Wadden Sea for only a part of their annual life-cycle, goose management should preferably be achieved at flyway level, with inclusion of all countries within the flyway. Such a flyway management plan was recently put forward for dark-bellied brent geese by the African Eurasian Waterbird Agreement (AEWA) (van Nugteren, 1997), but has not yet been endorsed by the governments involved. In the coming years, further expansion of feeding areas in the Wadden Sea and its immediate surroundings, e.g. agricultural ar-

eas along the mainland coast and polders at the islands, is likely for barnacle geese and potential conflicts with farmers might therefore increase (Koffijberg and Günther, 2005). Here, solutions regarding special goose management schemes (Laursen, 2002) are to be developed, aiming at a satisfactory co-existence of farmers and geese. Experiments in The Netherlands have shown that such an approach might also encourage public awareness and stimulate guidance for visitors in order to reduce general pattern of disturbance (Ebbing et *al.*, 2003).

12.2.5.5 Favorable food availability for benthivores

One of the most alarming issues concerning migratory waterbirds in the Wadden Sea has been the decline in many important species for which the Wadden Sea provides an indispensable stepping stone during migration and for which a major part of the total flyway population migrates through the Wadden Sea. The downward trends observed in many species are new since the 1999 QSR. For several species, notably the common eider and Eurasian oystercatcher, the recent EVA II project in The Netherlands provided evidence that the downward trends are related to deteriorating food stocks of blue mussels and cockles, this being due to both fisheries and natural conditions (weather, reproduction rates in bivalves), especially in the Dutch Wadden Sea. In addition, Scheiffarth and Frank (2005) indicated a Wadden-Sea wide conflict between birds (e.g. the common eider and Eurasian oystercatcher) and mussel fisheries. In the Danish Wadden Sea, mussel fisheries had been already restricted in the 1980s, after additional mortality had occurred among several waterbirds. In the Dutch Wadden Sea, in the late 1990s, licenses for shellfish (cockle) fisheries became subject to designation of closed areas and limitation of harvestable biomass in order to prevent over-exploitation. However, these measures were not able to stop the decline in waterbird populations. In June 2004, the Dutch government decided to phase out mechanical cockle fisheries from 2005 onwards, and to aim at the development of sustainable blue mussel fisheries in the next decade. In September 2004, licenses for mechanical cockle fisheries were withdrawn completely and a complete cessation of the mechanical cockle fisheries was decided upon starting 1st January 2005. In the Dutch Wadden Sea, this is an important step towards the target of a favorable food availability for birds. Concerning the development of sustainable blue mussel fisheries, however, monitoring and scientific investigations should be carried out

to be able to enhance proper management and evaluate the policy decisions taken. Similar assessments should also be made if other countries decide to expand shellfish fisheries in their territory. This implies that monitoring of mussel parameters in the entire Wadden Sea should be continued to be able to assess available food stocks for benthic feeders and to understand the underlying causes of changes in bird populations. Commercial landings of mussels provide only indirect evidence of the amount of mussels available for the birds, because most mussels landed for human consumption are already too large for the birds. Mussels fished for cultivation on subtidal culture lots (seed mussels), however, are of an appropriate size for the birds (Scheiffarth and Frank, 2005).

12.2.5.6 Natural flight distances

Natural flight distances are an important issue for several species (e.g. moulting common scoter, roosting Eurasian curlew), species-groups (seabirds, roosting birds, quarry species) and relate to a variety of human activities (hunting, marine wind farms, air traffic, outdoor recreation). Our knowledge, however, of flight distances, whether natural or disturbance induced, is rather limited for most species. Habituation may occur, and proper management measures are an issue of concern. Little is known of the flight distance of the common scoter or common eider with regard, for example, to the offshore wind farm developments and the associated ship traffic. There is also a need for better information on most roosting wader species in order to determine the key factors for flight distances to be used for better management of high-tide roosting sites with regard to tourists, zoning regulations, inland wind farms and other industrial and infrastructural developments. Experimental designed studies might be necessary in order to obtain essential data on this issue.

The study of the Eurasian curlew and the changes of hunting regime in Denmark have demonstrated that a rather minor change in hunting practice (the reduction of the period of open season) can considerably influence population dynamics of a species, whereas a seemingly major change, such as a hunting ban in a large area, later had less pronounced effects in this specific case. Curlews can now distribute according to the ecological conditions in the Danish Wadden Sea. In other areas, flight distances of geese have decreased as a consequence of both limitation of hunting and wise management of tourism. This development is an achievement complying with the target of natural flight distances

12.2.6 Recommendations

Recommendations are listed in accordance with the ecological targets of the Wadden Sea Plan.

12.2.6.1 Sufficiently large undisturbed roosting and moulting areas Management

- Further develop spatial and temporal zoning of recreational activities as well as a convincing visitor information system in order to reduce conflicts between roosting birds and recreational activities. In addition, more information is needed concerning natural flight distances, which is necessary to manage public access to areas in vicinity of roosting sites;
- Regulate hunting of small mammals (e.g. hare, rabbit) through trilateral management decisions in order to effectively reduce anthropogenic disturbance of roosting sites in salt marshes or inland during high tide;
- Assess the impact of civil air traffic (notably ultra-light aircraft) and introduce regulations at sites where severe disturbance is still reported, and also assess the remaining military training activities at important roosts (e.g. Vliehors at Vlieland, NL) and investigate impact of wind farms, especially for species other than geese;
- Provide sufficient protection measures for those sites that are part of the network of high tide roosts in the Wadden Sea but have been excluded from SPA designations. This especially applies to The Netherlands, where important inland roosts at agricultural sites behind the seawall are not fully subject to protection;
- Evaluate the potential disturbance from (offshore) marine wind farms and associated activities, with special attention for offshore-moulting common scoters.

Monitoring (TMAP) and research

- Start trilateral surveys of moulting concentrations of common shelduck, common eider and common scoter in the entire Wadden Sea, preferably by coordinated trilateral aerial surveys during early autumn, conducted as part of the JMMB monitoring program within the TMAP framework;
- Continue assessments of current status (numbers, distribution, threats) of moulting sites and develop conservation measures where necessary;
- Investigate macrozoobenthos communities in the offshore areas to assess factors determining the distribution of moulting common scoter.

12.2.6.2 Favorable food availability

Management

- Carefully evaluate the changes in the extent and methods of shellfish-fisheries, especially with regard to 'favorable food availability' for shellfish-eating birds';
- Monitor the remaining shellfish-fisheries (incl. fishing of seed mussels) and investigate their impact on food availability for birds;
- Encourage management on a flyway level for the barnacle goose and dark-bellied brent goose by including countries outside the Wadden Sea when developing further management plans;
- Seek solutions for the co-existence of farmers and geese through balanced management schemes, especially in agricultural feeding areas adjacent to salt marshes. This would also be beneficial to the target of natural flight distances (see below).

Monitoring (TMAP) and research

- Include parameters for 'benthos mass' and 'benthos quality' in the TMAP and evaluate current research programs on the macro-zoobenthic communities with regard to assessments of available food stocks for shellfish-eating birds. This will enhance the possi-

bilities to investigate backgrounds and causes for overall population changes in waterbirds observed in the Wadden Sea;

- Assess causal relationships between the occurrence of waterbirds and the availability of food stocks, preferably by experimental studies and modeling, in order to understand the processes involved in changes in waterbird numbers;
- Investigate trends in the different Wadden Sea countries in more detail and relate them to differences in policies and management in order to obtain insight into potential management-related causes behind the observed population changes;
- Assess possible changes in the distribution of geese caused by changes in salt marsh management using an analysis of re-sightings of individually marked birds.

12.2.6.3 Natural flight distances

- Investigate natural flight distances of birds in different situations (e.g. roosting, moulting, hunting and non-hunting areas, areas with different recreational pressure), preferably by experimental designed projects, with the aim of providing information to be applied for better protection of roosting and moulting sites.



Ringing of common eider
(Photo: G. Nehls).

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13. Marine Mammals



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Harbour seals
(Photo: K.-E. Heers)

13.1 Introduction

Marine mammals regarded as indigenous species in the Wadden Sea are the harbour (or common) seal *Phoca vitulina*, grey seal *Halichoerus grypus*, and harbour porpoise *Phocoena phocoena*. Several other marine mammal species, both pinnipeds and cetaceans, occur in the Wadden Sea and adjacent North Sea, either as stragglers or regular visitors. Stranding records since the 1999 Quality Status Report, show that occasionally five other species of seals are encountered in the Wadden Sea area and adjacent North Sea. These are: the harp seal *Phoca groenlandica*, hooded seal *Cystophora cristata*, ringed seal *Phoca hispida*, bearded seal *Erignathus barbatus* and walrus *Odobenus rosmarus*, all of which have a more northerly distribution. Cetaceans documented on the Wadden Sea coast are the white-beaked dolphin *Lagenorhynchus albirostris*, white-sided dolphin *Lagenorhynchus acutus*. Remarkable are the occurrence (live and dead) of large cetaceans in the Wadden Sea region since the 1999 QSR, notable six minke whales *Balaenoptera acutorostrata*, one humpback whale *Megaptera novaeangliae*, two fin whales *Balaenoptera physalus* and thirteen sperm whales *Physeter macrocephalus*.

The intention of this chapter is to describe the status of the harbour and grey seal, and of the harbour porpoise, as an update of the 1999 QSR and in relation to the Targets set for these species in the Wadden Sea Plan as well as the Seal Management Plan (Seal Management Plan, 1992, 1996, 2002).

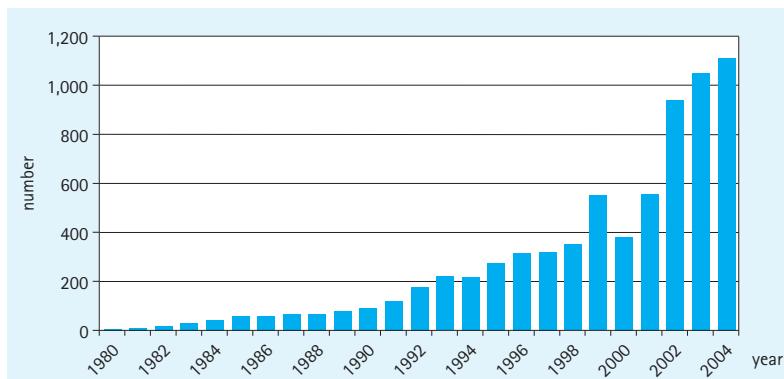
Target
Viable stocks and a natural reproduction capacity of common/harbour seal, grey seal and harbour porpoise in the tidal areas and the offshore zone.

According to the 1999 QSR, the population size of the harbour seal in 1988 was much higher than before the virus-epizootic of 1988 (de Jong *et al.*, 1999). At the Ministerial Conference in Esbjerg 2001, the positive development of the harbour seal population, which may be regarded as viable, was noted with satisfaction and an amended Seal Management Plan (SMP) for 2002–2006 was adopted (Seal Management Plan, 2002). The SMP will be revised on a regular basis.

The grey seal population in the Wadden Sea was relatively small and according to the 1999 QSR there was insufficient knowledge to judge whether the population was viable. Therefore, the new Seal Management Plan 2002–2006 also includes management actions for the grey seal, such as establishment of protected areas and improved monitoring.

Regarding the harbour porpoise, the 1999 QSR stated that there is too little knowledge about the population dynamics of the species to be able to evaluate the Target.

Figure 13.1:
Moult counts (March/April) of grey seals in the Dutch Wadden Sea.



13.2 Grey seal

Grey seals had been extinct in the Wadden Sea area (south-eastern North Sea) for centuries. Some 25 years ago, grey seals started to re-establish in a few colonies off the German island of Amrum and in the western part of the Dutch Wadden Sea (Reijnders *et al.*, 1995; Abt *et al.*, 2002). Most probably, the animals originated from the eastern UK, mainly the Farne Islands where grey seals are abundant.

In the western Dutch Wadden Sea, the development of the grey seal has been abundant (Figure 13.1). After the colony was established in the early 1980s, surveys during moult (March/April) show an annual increase of 20% on average (Reijnders and Brasseur, 2003), amounting to over a thousand animals counted during the moult in 2004. This increase is approximately 1½ times the maximum figure reported for an autochthonously growing grey seal stock in Canada (Zwanenburg and Bowen, 1990; Bowen *et al.*, 2003), which could be explained by a continuous influx from the British Isles (Reijnders *et al.*, 1995; Reijnders, 1996).

In the Wadden Sea of Schleswig-Holstein, recent grey seal pup production (minimum estimates) was between 20 and 30 (Figure 13.2). Occasional surveys in the peak moulting season (early April) counted up to 108 grey seals in total. In general, numbers have been increasing by 4–5%

per year on average. Numbers may largely be influenced by seasonal influx and should be interpreted in a wider geographic context, *i.e.* the North Sea (Abt *et al.*, 2002).

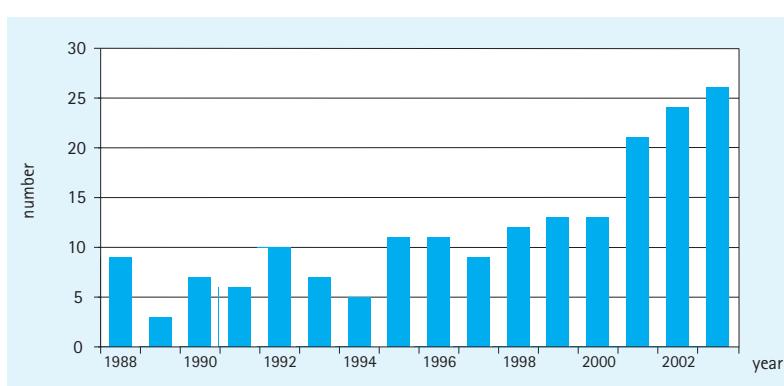
On the Düne isle (Helgoland, German Bight), 120 grey seals were observed in spring 2003 (R. Blädel, pers. comm.; Verein Jordsand, pers. comm.). There are signs of increasing colonies of grey seals elsewhere in German marine waters. In winter 2003, a maximum of 15 grey seals were seen on Borkum Riff and in summer 2003, 14 on Norderney. In the latter two areas, there does not seem to be any significant breeding.

13.3 Harbour seal

13.3.1 Distribution

At the end of the 1990s, the deployment of satellite transmitters on seals became possible, shedding new light on the seals' distribution. It appears that irrespective of the season, the animals travel hundreds of kilometers away from their haul-outs. Though still based on a restricted number of animals, it is clear that the seals from the Wadden Sea use the North Sea much more than realized before (Figure 13.3). One can hypothesize as to whether the seals' range may have changed, and if so, whether this is due to increased population size and/or to, for example, de-

Figure 13.2:
Minimum annual pup production of grey seals in the Wadden Sea of Schleswig-Holstein (Germany).



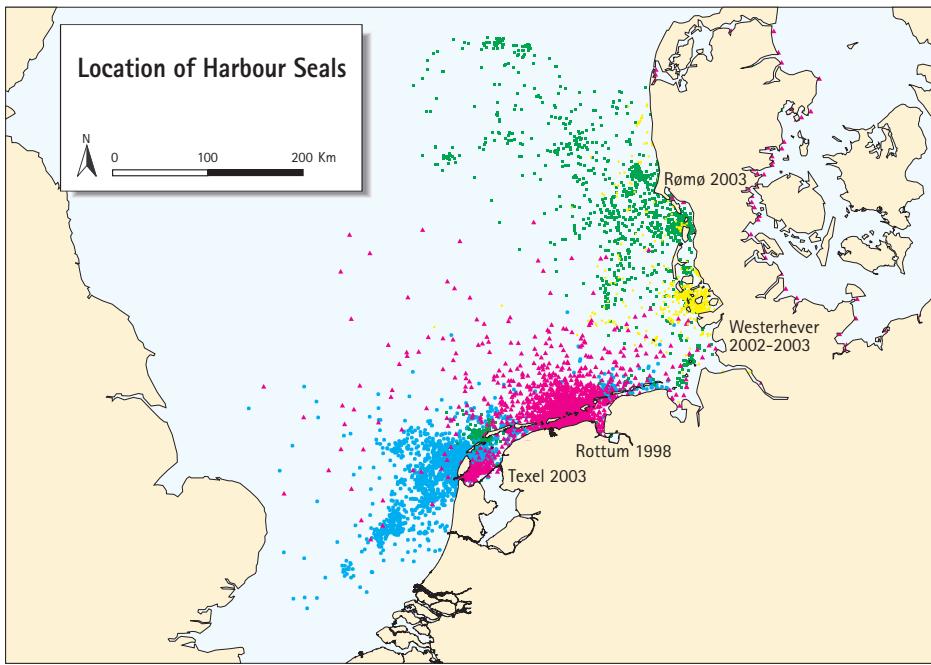


Figure 13.3: Locations of harbour seals revealed through satellite telemetry. Blue: seals tagged close to Texel in 2003; red: seals tagged at Rottum in 1998; green: seals tagged at Rømø in 2002; yellow: seals tagged close to Westerhever in 2002/2003.

ing fish abundance. Future research will show how different areas in the North Sea are utilized and how foraging opportunities may influence the spreading of the animals.

13.3.2 Developments and trends 1988 – present

After a disastrous Phocine Distemper Virus (PDV)-epizootic in 1988 (Kennedy, 1990), the harbour seal population recovered nearly fivefold, from some 4,400 animals counted in 1989 to 20,975 in 2002 (Figure 13.4).

The population growth, averaging 12.7% per year (Figure 13.5), was close to exponential dur-

ing these 14 years (Reijnders *et al.*, 2003a). There were no clear signs of density dependence, such as retarded population growth. Apparently, the carrying capacity (K) of the area has not been reached yet. The population size in 2002, estimated to be at least around 30,000 animals, is well below K .

The ratio of pups to total number of seals counted remained fairly constant during 1990–2002, and averaged 0.216 ($SD = 0.019$). Before the epizootic (1974–1987) that ratio had been lower, *viz.* 0.163 ($SD = 0.009$).

It is likely that survival and fertility of seals in the Wadden Sea were at their highest possible level

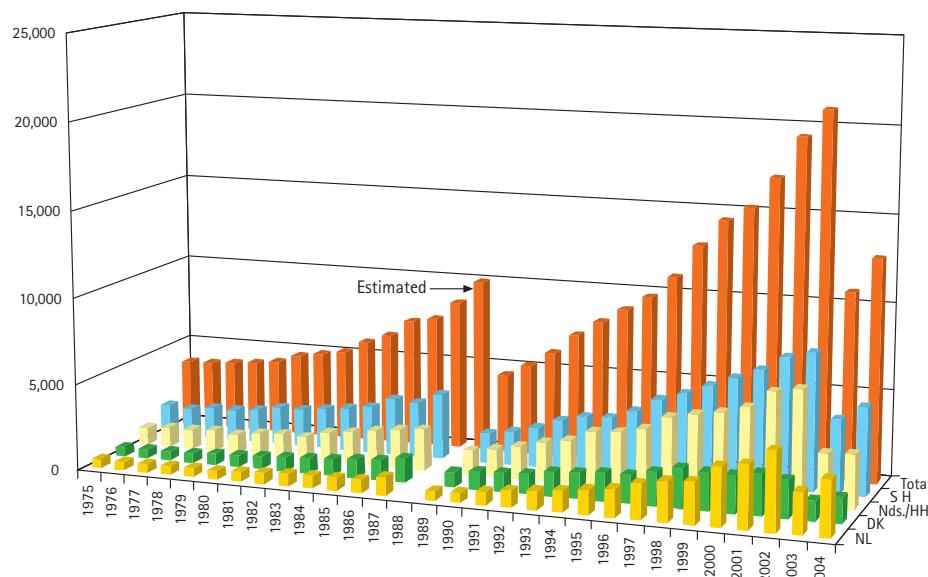
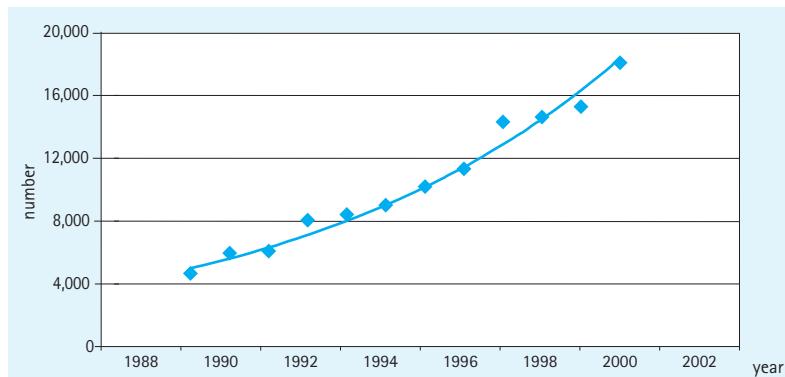


Figure 13.4: Number of harbour seals counted in the different Wadden Sea regions: The Netherlands (NL), Denmark (DK), Niedersachsen and Hamburg (Nds./HH), Schleswig Holstein (SH) and total.

Figure 13.5:
Calculated population trend of harbour seals in the Wadden Sea (line) for the period 1990–2001, based on annual aerial counts (symbols) during the moult (August).



in the 1990s (cf. Härkönen *et al.*, 2002). Therefore, it is safe to conclude that in terms of demographic parameters the population status of harbour seals in the Wadden Sea is satisfactory. Compared to an annual decline of 2.8% in 1960–1973, the population increased by 7% per year during 1974–1987, and after the 1988 epizootic the increase further grew to an average of 12.7% per year during 1989–2002 (Reijnders *et al.*, 1997; Abt, 2002).

In 2002, a second PDV-epizootic struck the population (Jensen *et al.*, 2002; Müller *et al.*, 2004). In 2003, only 47% of the expected number of seals (if no epizootic had occurred) was counted, *viz.* 10,800 animals. This number is comparable to the population count in 1996. Interestingly, the pup to total ratio that year (27%) was much higher than before (only 15% following the first epizootic). This offers good prospects for a quick recovery (Reijnders *et al.*, 2003b; section 13.3). Indeed, the surveys in 2004 showed that compared to 2003 the population has increased by 18% and the pup to total ratio was 29%, and a strong recovery seems to be on its way.

The 1988 epizootic somewhat changed the distribution of the harbour seal population throughout the Wadden Sea (Table 13.1). In 1987, Schleswig-Holstein was home to most of the animals (43%), and still is (almost 40%). Of particular interest is the relative growth in The Netherlands, where by 2001, 20% of the population was counted compared to 12% in 1987. Denmark apparently has lost importance, as demonstrated by the lower than average population growth from 1989

onwards, which virtually stopped from 1999 because of the relocation of a large group, almost a quarter of all 'Danish' seals, from haul-out sites just north of the border into the Schleswig-Holstein area.

13.3.3 Impact and consequences of the PDV disease

Short term trends

About 50% of the harbour seal population in the Wadden Sea was killed by the 2002 phocine distemper virus outbreak (Reijnders *et al.*, 2003c). As a consequence, the population size was again pushed well below the carrying capacity of the area. In the coming years, the stocks can be expected to recover. Growing exponentially at 12.7% per year, the population would take 6 years to reach the size that had been expected for 2003 (22,600 counted animals in August). Population recovery, however, may be faster and take only 4–5 years. This is because demographic data from distemper victims suggests that mortality was disproportionately high in adult males, and lower in adult females. The surviving population therefore contains an elevated proportion of mature females (about 40% instead of 30%), representing a high reproduction potential. This is already reflected in the unusually high ratio of pups to total number of seals counted in 2003. The demographic structure of the population will gradually return to stable proportions. For a limited period, an elevated productivity may prevail, resulting in elevated rates of population increase (14–17% per year), eventually resulting in a shorter recovery time, provid-

Table 13.1:
Distribution of the entire harbour seal population over the different Wadden Sea regions in different years, based on counts during the moult (August).

Year	NL	NDS	SH	DK	Total count
1987	12%	28%	43%	17%	8,296
1988		1 st PDV-epizootic			
1989	13%	28%	38%	21%	4,000
2001	20%	30%	37%	13%	17,900
2002		2 nd PDV-epizootic			
2003	22%	28%	39%	11%	10,817

ed that meanwhile no further PDV outbreak occurs.

Possible trends in the case of recurrent PDV outbreaks

What future may be expected for the seal population in view of distemper epizootics recurring at uncertain intervals? It is clear that the recovery and subsequent growth to carrying capacity levels would be severely disturbed. The shorter the interval between two epidemics, the lower the long-term population growth would be. Assuming that seals do not die from a second PDV infection while those not previously infected are subject to an average mortality of 50% (as observed in the 2002 epizootic), it would be expected that the long-term population trend will probably be positive at any interval length. The shortest possible interval is calculated to be two years, because only then there are enough susceptible animals around to start a new epizootic (Grenfell *et al.*, 1992). This scenario, however, should be taken with adequate caution, particularly because knowledge on phocine distemper characteristics such as persistency, virulence and transmission rates, is still scarce. Moreover, factors not taken into account, e.g. changes in environmental conditions in the seals' habitat, may lead to different mortalities than expected.

13.3.4 Health

Describing the health status of harbour seals in the Wadden Sea is complex because it is influenced by many different factors and can also be expressed in a wide variety of physiological parameters. A comparison of the outcome of autopsies carried out by members of the Trilateral Seal Expert Group on harbour seals in the periods 1979–1987 and 1999–June 2002 indicates that in pups perinatal disorders are the most significant threat. The occurrence of arthritis decreased during the second period (Siebert, 2003). The yearlings suffered mainly from lesions in the respiratory tract. In 1979–1987 these lesions were also present in older subadults, but not in 1999–2002. A second important observation during 1979–1987 was a high portion of fatal birth anomalies in adult females. Cases of fatal intestinal disorders in adult seals, such as intussusceptions and volvulus of the small intestine were observed in 2000–2002. The decline in occurrence of ecto-parasites, e.g. the seal louse *Echinophthirius horridus*, and the incidence of circum-umbilical ulcers, declined from approximately 15% in the early 1980s down to 1.5% around 2000.

Long-term field and pathological investigations

indicate that there is an improvement of the health condition in general. Further research is needed to investigate the cause of increased number of perinatal disorders in pups.

13.3.5 Environmental conditions of relevance to the status of the population

Anthropogenic impacts

Human activities potentially influencing the status of the harbour seal population include pollution, fisheries, shipping, tourist activities and more recently the building and operating of wind farms and gravel extraction. Hunting of seals was phased out in all Wadden Sea countries between 1962 and 1976.

Compared to the situation described in the 1999 QSR, the levels of the classical chemical compounds such as PCBs and DDT in seal tissue have continued to decrease (Härkönen *et al.*, submitted). Consequently, the impact of these pollutants on the seal population has significantly reduced compared to the period before the 1988 epizootic (Reijnders *et al.*, 1997).

With respect to the other human activities mentioned, not much new information has become available. Without ignoring the importance of the other factors, we consider it as a priority to address the aspect of adequate food availability in and outside the Wadden Sea. Besides the indirect method of relating seal distribution to fish distribution, technical solutions need to be developed to generate a more direct way of assessing the diet composition of the harbour seal.

Though population development is very well recorded in the area, distribution and habitat use away from the haul-out sites are still understood only at the level of individual seals rather than at a population level. In order to anticipate the effects of, for example, the development of large scale wind farms, information is needed on the relative importance for seals of the different ar-



Dead harbour seals,
Denmark 2002
(Photo: S. Tougaard).

eas, including haul-out sites, feeding grounds and migration routes. With respect to disturbance, information on 'dose and effects' of disturbance and possible habituation is needed. Only then will it be possible to estimate the cumulative effects of different human activities in some areas and to determine when and how these activities would affect the carrying capacity of the area for the seal population. Phrased differently: we need to find a way to assess how many new human activities such as wind farms and/or gravel extraction seals can stand in addition to the traditional human use of their habitat in the form of recreation and shipping.

Taking

Taking of live seals and their subsequent release after rehabilitation creates the risk of introducing pathogens which can have negative effects on the wild population. Based on information on growth and condition (reproduction, health, survival) of the populations, it was decided in 1991, and re-confirmed in 1994, by the responsible authorities of the Wadden Sea countries, that taking, rehabilitation and subsequent release of seals is not necessary from a biological nor a management point of view. According to the Seal Management Plan 2002: 'the number of seals taken from and released to the Wadden Sea should be reduced to the lowest level possible' (Trilateral Seal Expert

Group-plus, 2002). New data, from 2002 onwards, will demonstrate whether the trilaterally developed guidelines for handling of seals will successfully result in a significant reduction of the number of animals taken, rehabilitated and released per total numbers in the respective (sub)population.

According to the Seal Management Plan (SMP), for all dead animals found a trilaterally agreed minimum number of parameters should be measured, and the data forwarded to the responsible state agencies and stored in a database. Data to be collected should at least include: number, date and place found, length, age and sex. Together with post-mortem examinations, this data will assist in evaluating the health status of the population. It is essential that the effort of the search is recorded as well.

13.4 Harbour porpoise

13.4.1 Around the West Frisian islands – Dutch waters

The only recent North Sea-wide survey of harbour porpoises is the SCANS mid-summer survey of 1994 (Hammond *et al.*, 2002). The density of harbour porpoises off the coast of The Netherlands and Niedersachsen (area H) was 0.09 km^{-2} . Within the Wadden Sea itself and the adjacent North Sea area, dedicated surveys do not exist. Opportunis-

Figure 13.6:
Increase in sightings of
harbour porpoises in The
Netherlands since 1972,
including effort-corrected
sightings from sea-
watching sites (dark blue)
and accidental reports
(light blue).

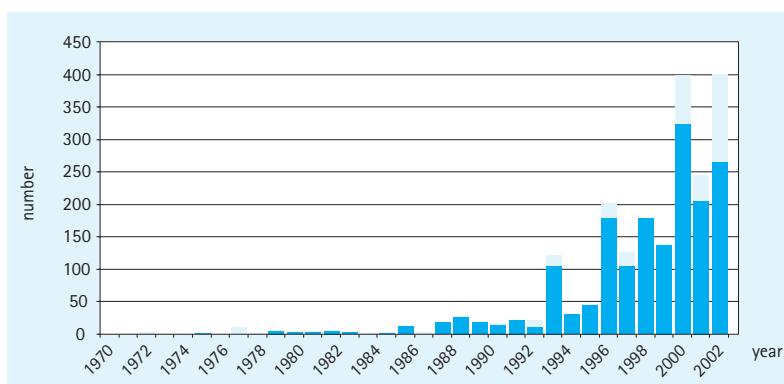
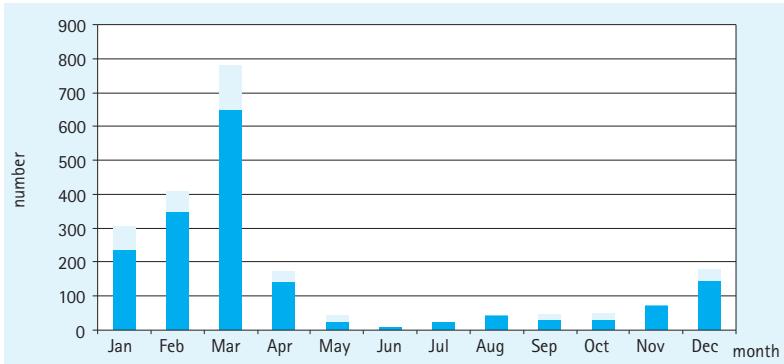


Figure 13.7:
Seasonal pattern in
sightings of harbour
porpoises in The
Netherlands, including
effort corrected sightings
from sea-watching sites
(dark blue) and accidental
reports (light blue).



tic observations show that here the number of sightings is consistently very low, and virtually restricted to areas with turbulent water and channels between the islands. Along the North Sea mainland coast in The Netherlands (*i.e.* south of Den Helder) several fixed sites exist, providing very frequent sightings and a clear-cut seasonal pattern (Figures 13.6 and 13.7).

Harbour porpoises were initially winter visitors in Dutch coastal waters, but have become year-round visitors more recently. Contrary to the period mid 1980s to 1995, adult females with small offspring have been observed with increasing regularity in recent years (Camphuysen, 1994; Camphuysen, 2005). Documented strandings show increasing numbers washed ashore, and a similar trend of more frequent strandings of young individuals (Addink and Smeenk, 1999). It is postulated that the same trends and seasonal patterns occur at the West Frisian islands, which is corroborated by opportunistic sightings only. It is hypothesized that the increase in harbour porpoises in the Dutch waters since the mid 1990s until now, is linked to a distributional shift of harbour porpoises in the North Sea rather than population fluctuations. The re-distribution may be triggered by local reductions or regional changes in principal prey availability (Camphuysen, 2005).

13.4.2 In the German Bight

During the previously mentioned SCANS survey of 1994, the highest density of porpoises in all sub-regions in the North Sea was found in the

waters of Schleswig-Holstein (area Y), and amounted to 0.812 km^{-2} . The extraordinarily high proportion of mother-calf groups in that area was remarkable. More recently, during May-August in 2002 and 2003, aerial surveys were conducted in the German EEZ of the North Sea (Figure 13.8) to assess harbour porpoise distribution, density and abundance.

In both 2002 and 2003 the highest density of porpoises was seen in area C and the lowest in area D (Table 13.2).

The high density area is larger than previously thought (Sonntag *et al.*, 1999) and not just restricted to the coastal waters (Scheidat *et al.*, 2003). The offshore regions A and B had similar densities, both within and between years. The density and the resulting abundance estimates were different between the years 2002 and 2003, but the overall patterns of mean abundance in the German EEZ of the North Sea are very similar between years.

The overall mean abundance of harbour porpoises in the German EEZ of the North Sea, in summer 2002 and 2003, amounted to around 36,500 animals (Table 13.3).

Because of the very high density of harbour porpoises off the coast of northern Schleswig-Holstein, an area which is also an important calving ground, a whale sanctuary off Sylt and Amrum was established in 1999. Within the whale sanctuary, it is not allowed to seriously harm whales, and – according to a revised coastal Fishery Order ('Küstenfischereiordnung') – to use bot-

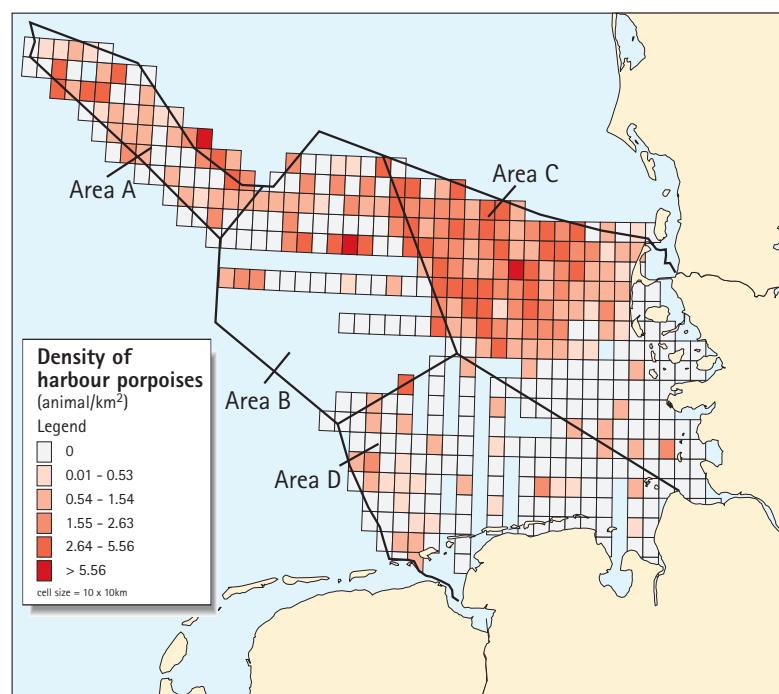


Figure 13.8:
Map showing the distribution of harbour porpoises in the German EEZ of the North Sea. Area A = Entenschnabel; B = Offshore; C = Nordfriesland; D = Ostfriesland. For each cell ($3'$ latitude by $6'$ longitude), density is shown in animals per km^2 . Results are shown of flights conducted under good or moderate conditions during May – August in 2002 and 2003.

Table 13.2:
Density and abundance of porpoises from May to August in 2002 and 2003 in four areas of the German EEZ of the North Sea. A = Entenschnabel, B = Offshore, C = Nordfriesland and D = Ostfriesland. The coefficient of variation (C.V.) was calculated for each area using the values for 2002 and 2003 as samples. The mean shown is the geometric mean based on log-transformed data.

Table 13.3:
Calculation of overall harbour porpoise abundance in the German North Sea EEZ during the months May to August in 2002 and 2003. Mean presented is based on the log-transformed data and corresponds to the geometric mean. C.V. = coefficient of variation; C.I. = confidence interval.

Area	Size (km ²)	Effort (km ²)	2002		Effort (km ²)	2003		Abundance per area 2002	Abundance per area 2003	Mean abundance 2002-2003	C.V.
			No. of porp.	Density (animals/km ²)		No. of porp.	Density (animals/km ²)				
A	3,903	3.9	4	1.03	110.3	90	0.82	4,003	3,184	3,570	0.18
B	11,650	56.4	33	0.59	58.1	42	0.72	6,821	8,427	7,582	0.17
C	13,668	231.3	353	1.53	379.4	703	1.85	20,857	25,329	22,986	0.15
D	11,824	179.7	41	0.23	97.9	18	0.18	2,698	2,174	2,422	0.17

tom set nets higher than 1.3 m and a mesh size >150 mm, to conduct industrial fishing or to use drift nets. The whale sanctuary is enshrined in German National Park Act and the Coastal Fisheries Order, which are only valid for German fishermen. Therefore, this national legislation should be implemented into EU Fishery Legislation. As a first step, the EU-notification of the revised Coastal Fishery Order was applied for.

2002	2003	Mean (geometric)	C.V.	C.I.
				Lower 95% Upper 95%
34,381	39,115	36,672	0.10	16,154 83,247

13.4.3 In Danish waters

Little information is available about harbour porpoises inside the Danish Wadden Sea. A three-year national campaign in 2000–2002 among pleasure boat owners resulted in 13 sightings of porpoises in waters around Rømø, Mandø and Fanø, of which three were with a calf and one sighting comprised one–five animals (Kinze *et al.*, 2003). This number of sightings may seem low compared to German and Dutch waters, but is probably a reflection of the much lower level of boat traffic and hence also much lower observation activity.

Much more information about abundance is available in the waters west of the islands and especially around Horns Reef, extending 40 km westwards from the Skallingen Peninsula. This information (Figure 13.9) comes from ship-based surveys conducted in 1987–2003, originally aimed at counting seabirds. Since 1999, dedicated por-

poise surveys have been conducted in the area, in connection to the offshore wind farm on Horns Reef. These surveys revealed the presence of 500–1,000 porpoises in the Horns Reef area, with substantial variation, however, from survey to survey. Average densities are comparable to those found in the SCANS survey, viz. 0.65 and 0.81 animals/km² for areas L (eastern part of Fisher) and Y (Danish and Schleswig-Holstein parts of the Wadden Sea) respectively.

The survey data from Horns Reef (Figure 13.9) does not show any trend in the abundance of porpoises at Horns Reef over the last 18 years.

13.5 Conclusions

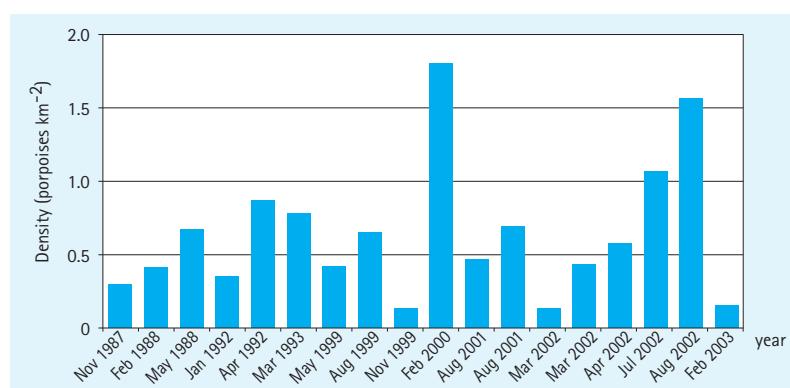
13.5.1 Scientific assessment – Issues of concern

Harbour seal, grey seal and harbour porpoises are species included in Annex II of the EC Habitats Directive.

13.5.1.1 Harbour seal

After a successful recovery from a PDV-epizootic in 1988, the harbour seal population in the Wadden Sea was struck again by a seal virus (PDV) in 2002. In 2003, numbers were only 47% of those that would have been expected if no epizootic had occurred. Pup production in 2003 (number of pups per total number counted) was higher than before the epizootic. This can be explained by the skewed age and sex composition of the surviving population. The demographic structure will gradually return to a stable composition. It is essential to continue close monitoring of the population to assess the recovery from its depleted size.

Figure 13.9:
Harbour porpoise densities from ship-based visual surveys at Horns Reef, DK. Surveyed areas are not identical and survey conditions (sea state, eye height etc.) vary between surveys. Figures are not corrected for animals missed by the observers ($g(0)$ correction). Data source: Tougaard *et al.*, (2000), Skov *et al.*, (2002) and Tougaard *et al.*, (2003).





Harbour seals
(Photo: S. Tougaard).

Recently, satellite telemetry was used to investigate habitat use of harbour seals. This revealed that seals use the North Sea to a much larger extent, in terms of numbers as well as range, than thought before. It is therefore considered of importance to intensify studies focused on foraging ecology to identify critical habitats for this species in the North Sea.

The increasing human exploitation of marine waters gives rise to a new concern. In particular the booming wind farm industry in the North Sea, and to a lesser extent gravel extraction, poses potential threats to harbour seals through interference with foraging and migratory behavior. This issue needs to be addressed as a matter of priority.

13.5.1.2 Grey seal

The grey seal population in the Wadden Sea is growing. In the Dutch Wadden Sea, the development of the grey seal population since its establishment in the early 1980s has been abundant

with an average annual increase of 20%. Some of the growth can be attributed to influx from colonies of the UK east coast. In the Wadden Sea of Schleswig-Holstein, the numbers have been increasing by on average 4–5% per year. Outside the reproductive colonies in the Dutch Wadden Sea and in the Wadden Sea of Schleswig-Holstein, there are signs of a more recent establishment of grey seal colonies in the Wadden Sea of Niedersachsen (Borkum Riff and Norderney) and the Isle of Helgoland (German Bight), until now without any significant breeding.

The conservation of grey seals in the Wadden Sea must involve effective protection of colony sites particularly during the breeding season (November–January) and moulting season (March–April). This is currently implemented in Schleswig-Holstein, but not in The Netherlands, where major colonies fall outside the Conservation Area, and strict protection of seals is only provided from 15 May till 1 September.



Grey seals
(Photo: H.-U. Rösner,
WWF).



Harbour porpoise
(Photo: B. Lammel, WWF).

The other concern is our lack of knowledge about the basic biology of this species in the waters of the entire Wadden Sea. For this indigenous species, which is included in the Seal Management Plan, studies of changes in numbers as well as habitat use should be initiated in order to obtain data essential for designing appropriate management.

13.5.1.3 Harbour porpoise

Since the SCANS surveys in 1994, no further North Sea-wide comprehensive survey has been carried out. Opportunistic observations within the Dutch Wadden Sea show that the number of sightings is still very low. Along the Dutch mainland coast fixed observation sites exist which supply more regular counts. This data demonstrates that since the mid-1990s harbour porpoises are becoming year-round visitors, mother-calf groups have been observed with increasing regularity and the number of harbour porpoises sighted have increased considerably by 41% per annum.

Aerial surveys of harbour porpoises in the German Bight carried out in the summers of 2002 and 2003 revealed that the overall mean abundance of harbour porpoises in the German EEZ of the North Sea amounted to around 36,500 animals.

Information about harbour porpoises in the Danish Wadden Sea is scarce. Porpoises, including mothers and calves, are observed, but no density data is available. Much better data is available for the areas west of the Wadden Sea islands. Since 1987, boat surveys originally designed for bird monitoring also provided data on the occurrence of marine mammals. Since 2000, dedicated porpoise surveys have been conducted in connection with the offshore wind farm on Horns Reef. These surveys reveal the presence of 500–1,000 porpoises

in the area, but show substantial variation from survey to survey, without any trend in the abundance over the last 18 years.

Fortunately, the recent development of wind farms in the North Sea created the opportunity to investigate the distribution, abundance and density of porpoises in North Sea areas adjacent to the Wadden Sea. Until then, lack of knowledge hampered the assessment of the status of the harbour porpoise in these waters. Continued monitoring of harbour porpoises is therefore considered a priority. Detailed suggestions to that effect are included in the section Recommendations for research and monitoring.

At the same time, however, these offshore developments pose a potential threat to the harbour porpoise population(s). Disturbance at feeding and nursing grounds, as well as effects on migratory behavior, may be expected, and should be, and already partly are, the subject of Environmental Impact Assessment (EIA) studies. These potential effects come on top of existing pressures such as by-catch of fisheries and pollution. By-catch in particular is considered the main threat to harbour porpoises in the North Sea and the Baltic (e.g. ASCOBANS, 2003). By-catch is occurring in coastal waters adjacent to the Wadden Sea and along the Dutch mainland coast, as demonstrated by Smeenk *et al.* (2004) and Siebert *et al.* (submitted). The magnitude of the by-catch in terms of numbers per stock/population size in the Wadden Sea and adjacent North Sea is unknown and therefore the sustainability of the porpoise by-catch in Dutch, German and Danish EEZ waters should be addressed, including possible mitigation measures.

13.5.2 Status and assessment of the target implementation

Target

Viable stocks and a natural reproduction capacity of common/harbour seal, grey seal and harbour porpoise in the tidal areas and the offshore zone.

Viability

Viability can be defined as the survival of a population in a state that maintains its vigor and its potential for evolutionary adaptation (Soulé, 1987). It is generally agreed that there is no single value that can be globally applied in all situations. Two components of viability analysis may serve to indicate the persistence of a given population, *i.e.* genetic criteria and risk of extinction.

From an inbreeding point of view, the minimum size of a mammal population with life history parameters such as the harbour seal is considered to be 500 individuals. It is evident that the size of the Wadden Sea harbour seal population is far beyond that threshold and can therefore be regarded as viable.

The situation with respect to the grey seal is more complex. The colonies in the Dutch Wadden Sea number at least 1,100 specimens, however, data on life history parameters such as reproductive performance as well as survival in the colonies, is lacking. It is assumed that immigration from the east coast of the UK (notably the Farne Islands and Scotland) still has a prominent influence on the developments of these colonies, but the extent of this is unknown. Therefore, no conclusions can be drawn about the self-supporting capacity of these grey seal colonies.

Besides the fact that there has never been a harbour porpoise population in the Wadden Sea and numbers observed are rather a reflection of the distribution of harbour porpoise population(s) or stocks in the adjacent North Sea, data to evaluate the target for this species is lacking.

The other criterion, risk of extinction, can only be addressed for harbour seals, as data for grey seals and harbour porpoises is lacking.

The re-occurrence of mass mortalities has prompted the question of how recurrent epizootic outbreaks may affect the harbour seal population. Harding *et al.* (2002, 2003) have shown that the extinction risk, *i.e.* the risk to decline to 10% of the initial population size, for the Kattegat-Skagerrak harbour seal population increases from 0.09 in the absence of epizootics to 0.56 in the presence of epizootics. This is on the assumption of

an upper boundary level of 50,000 individuals. If no boundary level is assumed, the calculated risk is negligible in the absence of epizootics or 5% with epizootics occurring. Much of the outcome of the risk analysis is dependent on the assumed immunity, frequency of epizootics, meta-population structure, upper boundary levels and sampling variability. Future changes in these values are unknown and therefore it is not possible to exactly state what the risk for extinction is and subsequently whether viability of the population will be seriously impeded. However, it is considered safe to assume for the harbour seal population in the Wadden Sea, that with the PDV properties as operative in that area during the last epizootic, there is no significant risk of quasi-extinction.

Natural reproduction capacity

For the parameter 'natural reproduction capacity' no quantification can be given for either the harbour seal, grey seal or harbour porpoise, because of insufficient knowledge of this parameter. It is possible to provide a qualitative indication on the reproductive status of the harbour seal. Though no data is available on a straightforward measure such as fertility amongst the female section of the population, comparison of growth rate, calculated per capita birth rate and death rate in this population with similar data from harbour seal populations elsewhere may provide some insight in their 'natural reproduction capacity'. Based on the data obtained for the Wadden Sea harbour seal population and the population in the Kattegat-Skagerrak (Abt, 2002; Reijnders and Brasseur, 2003), it is concluded that the reproduction capacity of the Wadden Sea harbour seal population was at a satisfactorily level.

13.5.3 Recommendations

In the Seal Management Plan (SMP) 2002-2006, the required effort and objectives as well as management, research and monitoring actions for the running time-period are given. These relate to habitats, pollution, wardening, research and monitoring, taking and exceptions for taking and public information (Trilateral Seal Expert Group-plus, 2002). The SMP contains the main recommendations regarding seals and the listed actions in the SMP are still relevant and should be implemented.

In addition to the SMP, the following recommendations are emphasized especially because of the recent increase in numbers of the seals, and rapidly developing offshore wind farms.

13.5.3.1 Recommendations for management

Because of increasing numbers of grey seals in the Wadden Sea and at Düne Helgoland, it is recommended to ensure that grey seal colonies are protected. Reserves should be maintained, extended and established in such a way that disturbance is limited to a minimum.

For recommendations with respect to the harbour seal, see SMP 2002-2006.

For the protection of the harbour porpoise, the national regulations of the German Whale Sanctuary off Sylt and Amrum should be incorporated into EC legislation.

13.5.3.2 Recommendations for research and monitoring

Given the severe depletion of the Wadden Sea harbour seal population in 2002, it is emphasized that monitoring of this population should be continued at the same level of intensity as in the past decennium, to enable its recovery to be followed closely.

In view of the increasing awareness that harbour seals from the Wadden Sea use the North Sea as feeding grounds, and the growing pressure on fish resources in the North Sea, it is recommended that research into the feeding ecology (e.g. diet composition and foraging sites) of this species should be continued and intensified.

Recognising 1) the rapidly expanding human offshore activities such as construction and operation of wind farms and gravel extraction, and 2) the evident importance of the North Sea as feeding grounds for harbour seals, it is recommended that alongside ongoing studies about impact of those activities on harbour porpoises, priority should be given to include studies focusing on impacts of those activities on harbour seals, in particular foraging and migratory behavior.

In order to design adequate management measures and enable the evaluation of the targets for grey seals and harbour porpoises, it is recommended that monitoring grey seals and harbour porpoises should be continued or initiated in the framework of the TMAP.

Because of increasing numbers of grey seals in the Wadden Sea and at Düne Helgoland, it is considered necessary to start studies on grey seal basic population biology such as population/stock size, pup production, and distribution during and outside the breeding and moult season.

By-catch by fisheries of harbour porpoises does occur in the waters adjacent to the Wadden Sea. It is unclear what the impact is on the stocks concerned. As a start, it is recommended that the location and extent of the by-catch should be investigated.

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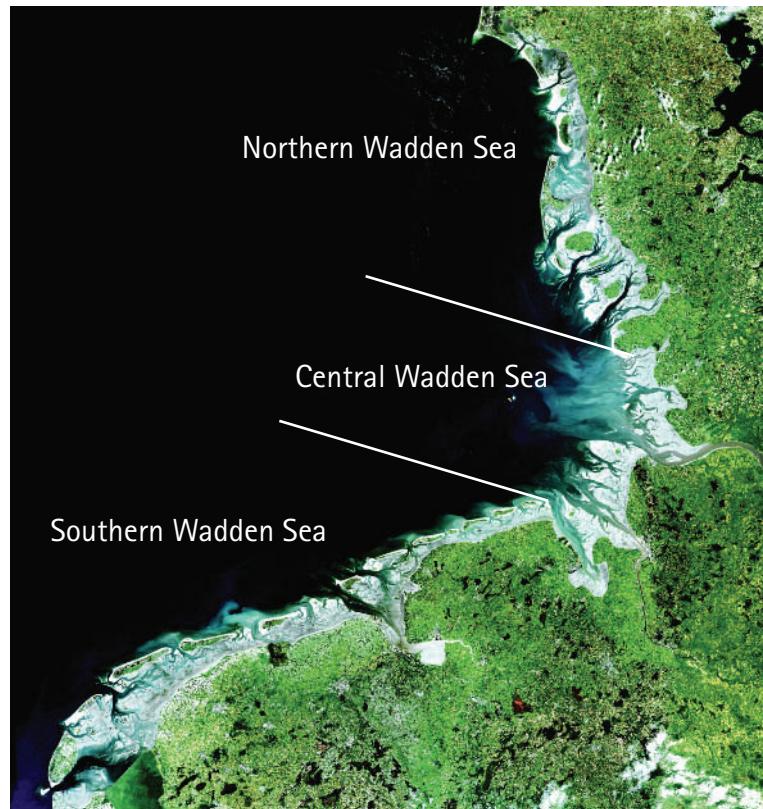
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14. Synthesis of Ecosystem Developments



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Figure 14.1:
The Wadden Sea divided
into three sub-regions.

14.1 Introduction

The preceding chapters of this Quality Status Report have been structured very much according to the ecological targets as formulated in the Wadden Sea Plan of 1997 with chapters 1 and 2 providing an update of the trilateral conservation policy and legislation together with an overview of the various human activities that – the one more than the other – act as pressures against the natural processes in the Wadden Sea ecosystem. The report describes and evaluates recent developments in order to guide further management decisions. In this chapter, we present an overview written from an ecosystem perspective, summarizing the major trends and events, focusing on geographical differences within the system, on its dynamics and productivity. In doing so, we hint at priorities for a further development of targets, monitoring and management.

14.2 Some trends and events

Coastal ecosystems such as the Wadden Sea are subject to continuous and ongoing change, never attaining final equilibrium when considered in a long time frame. There are trends in sea level, water currents, climate or nutrient supply, interspersed by particular events such as a severe winter in 1995/1996, three very warm summers in a row

from 2001 to 2003 facilitating the spread of introduced Pacific oysters, and two disastrous Phocine Distemper Virus epizootics in 1988 and 2002 each of which halved the harbour seal population. Seagrass beds are beginning to recover. A sign of high habitat quality may be that breeding populations of Mediterranean and great black-backed gulls as well as spoonbills have been able to expand their range in the Wadden Sea. On the other hand, there seems to have been a recent decline of migrant birds on tidal flats in most parts of the Wadden Sea.

14.3 Management

Superimposed on such trends and events are attempts by the authorities responsible for an integrated environmental management, aiming for – as far as possible – a natural status of the Wadden Sea ecosystem, as agreed in the Trilateral Wadden Sea Plan, Stade 1997. Management was successful in the last decade. Riverine loads of nutrients and several pollutants have declined further. Many artificial salt marshes are gradually developing natural structures. Almost all cockle fishery has been stopped to reduce disturbances of the benthic system and to improve food resources for mollusc-feeding birds. The harbour seal population seems to be in a viable state in spite of epidemics. A better protection of the moulting area of the

European shelduck population and of breeding colonies of little tern have been achieved.

However, there are also developments of an adverse nature or of which appropriate observations are lacking. Beaches, for example, still remain a critical habitat because of increasing human use in all seasons, affecting the breeding success of great ringed and kentish plover and possibly the recolonization of grey seals. Top consumers including humans are still exposed to pollutants. Hormone-disrupting substances may form a new threat. Some developments with interacting processes and confounding effects, such as reduced nutrient loads and their final effects on benthic productivity and carrying capacity for birds, are not sufficiently understood and it is not clear what management options should be chosen.

14.4 Geographical constraints

The Wadden Sea is a wide open system subject to processes originating from outside the region, and only partly amenable to current management. Examples are the increasing size of sea-going vessels entering the estuaries and the absence of juvenile cod because of overfishing and climate change in the northern Atlantic. In some cases research is needed to distinguish between internal and external causes as in the recently declining numbers of flatfish and of migratory wading bird species. The analyses of such cross-boundary developments as well as the corresponding management efforts have to be performed in collaboration with partners outside the Wadden Sea area. It should be kept in mind that the boundaries of the Wadden Sea ecosystem are far beyond those of the Wadden Sea Cooperation Area.

The persistent absence of large anadromous fish – salmonids and sturgeon – requires coherent restoration programs from upstream reaches of rivers through the estuaries into Atlantic waters. The observed spread far into the North Sea of seals tagged at the Wadden Sea coast necessitates studies of food availability and threats in an area beyond the Wadden Sea if the efficiency of protective measures within the Wadden Sea by the Seal Management Plan is to be evaluated.

In addition to external linkages, differences in developments between sub-regions within the Wadden Sea need more attention. For processes in the water, the perpendicular orientation of the southern versus the northern Wadden Sea coastline may be important. Exposure to wind and waves affects these two coastlines differently, most probably causing differences in exchange processes

between the Wadden Sea and the adjacent North Sea. With respect to locations of major freshwater discharges (e.g. Rhine-Meuse, Weser, Elbe), sub-regions may need to be discerned. When also considering tidal range, a central Wadden Sea (from Jadebusen to Eiderstedt peninsula) with more than 3 m tidal range may be distinguished from the southern and northern sub-regions, which mostly have a smaller tidal range (Figure 14.1).

Accelerated sea level rise, especially increasing high tide level, is apparent in the northern but not in the southern Wadden Sea. Phytoplankton biomass in summer and nitrogen remineralization in autumn are about twice as high in the southern as in the northern Wadden Sea, indicating differences in eutrophication level. Intertidal seagrass beds declined until the 1990s in the southern but not in the northern Wadden Sea. Bivalve recruitment patterns differ conspicuously between Wadden Sea sub-regions. While the last good spatfall of blue mussels in the northern Wadden Sea dates back to 1996, several significant recruitment events have occurred recently in the eastern Dutch Wadden Sea. The causes of these geographical patterns are not known. A better understanding of differing processes and developments between sub-regions of the Wadden Sea is necessary for refining targets, and to adjust monitoring and management schemes accordingly.

Sub-regional differences not only occur in the water but also the dune vegetation differs substantially between southern and northern Wadden Sea islands. In the south, dune grassland and scrubs dominate while dune heath prevails in the north. These vegetational differences have divergent effects on the associated fauna and require different management approaches.

14.5 Morphodynamics

At a coast with a flat land fronting a shallow sea, slight changes in sea level, tidal range, storm frequency, currents and river runoff strongly affect morphodynamics and ecosystem processes. Consequently, the ecosystem is highly sensitive to man-made changes of shoreline shape and position, operation of freshwater sluices or dredging in estuaries to accommodate larger sea-going vessels. Some human interferences inhibit natural morphodynamics while others facilitate dynamics beyond natural rates (Figure 14.2).

In the Wadden Sea, the most fundamental inhibitor of natural morphodynamic adjustments to sea level rise is the dike line along the mainland coast, constructed and maintained to provide pro-

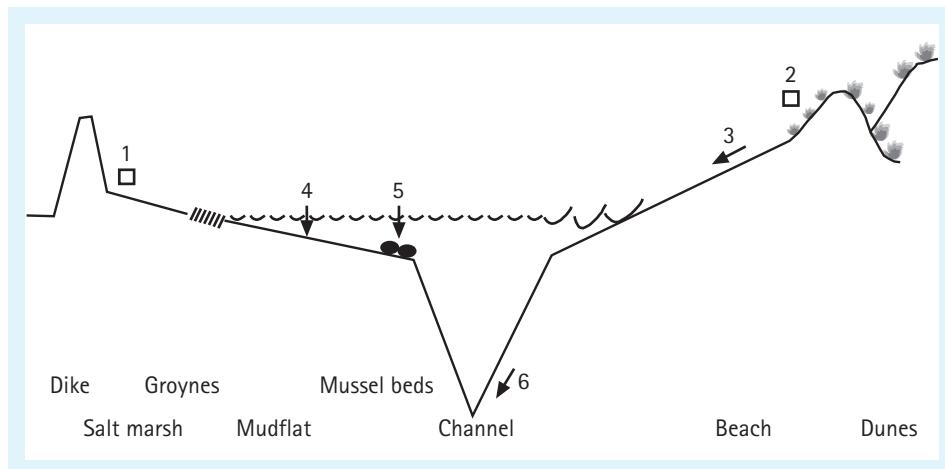


Figure 14.2:
Human interference
inhibiting and facilitating
natural morphodynamics.
1: salt marsh confined
between dike and groynes,
2: dune stabilization,
3: nourishment of beaches
and foreshore,
4: decreasing fine particle
deposition on intertidal
flats, 5: dredging and
bottom trawling by fishery,
6: deepening of channels
for shipping.

tection against flooding. Salt marsh succession is truncated at the upper end by a dike. Pioneer vegetation at the lower end usually requires protection by brushwood groynes in order to develop. Between dikes and groynes the vegetation is aging. The further the level of a salt marsh has grown upward through sediment deposition during spring and storm tides, the more conspicuous is the receding cliff at its seaward side. Where this progressive edge erosion occurs close to a dike, it is soon stopped by revetments made out of stone or asphalt. Dynamic development has then ceased altogether.

Many birds use salt marshes and wet meadows for breeding. Several breeding wader species, however, including black-tailed godwit, dunlin and ruff are declining and some have become nearly extinct. They depend on the quality of salt marshes and meadows, which obviously has been inadequate for the demands of these species during the last decade. This may not be related to morphodynamics but more to other habitat management decisions. Except for some tips of sandy islands, dune dynamics are usually inhibited by a combination of planting marram grass and of airborne eutrophication, which facilitates a dense grass cover. This stabilization allows for permanent housing or road infrastructures in or close to dune areas and leads to a dominance of late successional stages in vegetation.

Artificial facilitation of morphodynamics occurs where beach erosion is compensated by sand replenishments. Although this measure is a better environmental practice than traditional hard defences, it results in a higher rate of change in beach and foreshore morphology because beaches are set back by sand nourishments to an earlier state

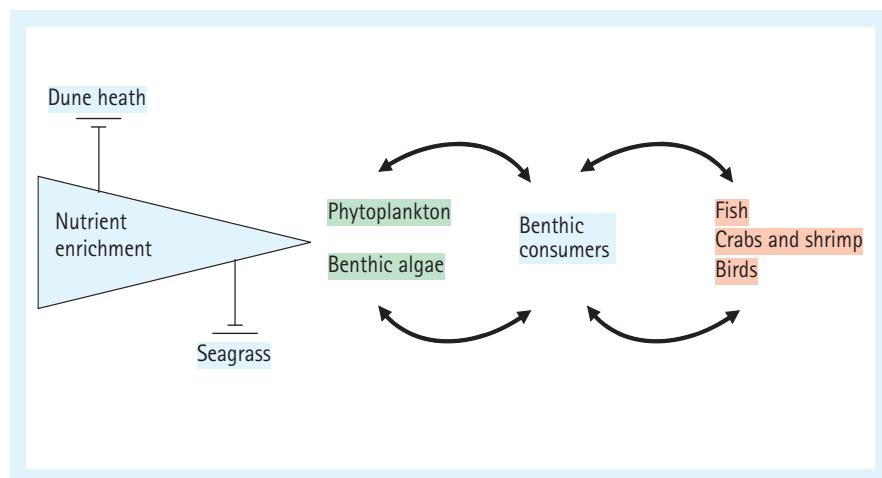
of succession. Furthermore, disturbance and instability are imposed at sand extraction sites as well.

Three processes may give rise to a sandier Wadden Sea at the expense of silty or muddy flats. On tidal flats adjacent to a dike and fronting a straight coastline, sediment stability and mud deposition is decreasing with sea level rise. This conclusion is based on grain-size distributions and modeling. Such a gradual process towards a more sandy Wadden Sea has far reaching consequences for all benthic organisms living on near-shore mud flats as well as for the crustaceans, fish and birds which forage there. Morphodynamics are also facilitated in the lower intertidal zone and subtidal bottoms. This is caused by dredging or trawling for bivalves, shrimp or flatfish and may prevent recovery of sabellarian reefs. In addition, removal of blue mussel beds or the maintenance of mussel bottom cultures are inhibiting mud deposition and promote mobile sandy bottoms.

In estuaries, the continuous dredging of one major channel which has to accommodate ever larger vessels initiates sediment instability. The deeper the channel, the higher the inshore migration of sand to restore the previous depth and the faster the currents flushing through. On the other hand, former side channels become silted as in the Ems and Weser estuaries.

The desire for morphological stability at the shore and in dune areas on the one hand, and the facilitation of sediment dynamics in the intertidal zone and below on the other, are both in conflict with the target for natural morphodynamics. Some mitigation is possible. Good examples are the cessation of artificial drainage and

Figure 14.3:
Effect chain of nutrient enrichment in the Wadden Sea area: Inhibiting dune heath and seagrass, facilitating phytoplankton and benthic algal growth, and these create reciprocal interactions with various groups of consumers.



a moderation of livestock grazing on mainland salt marshes, the end of mechanical cockle dredging or agreements to save intertidal mussel beds from exploitation in large parts of the Wadden Sea. However, there is still a wide potential for restoration and mitigation, particularly along shorelines to avoid hard sea defenses.

14.6 Productivity

The Wadden Sea is praised for its great productivity, serving as a nursery for North Sea fish and as a turntable for large flocks of migrant birds (Figure 14.3). Nevertheless, some of its characteristic plants such as seagrass flourish best under oligotrophic conditions and heath vegetation in the dunes is threatened by eutrophication. Thus, high productivity should not be a general aim for all habitats. The tidal area of the Wadden Sea is to be regarded as a eutrophication problem area with a phytoplankton production exceeding natural background conditions.

Presumably, the peak of riverborne eutrophication was passed in the 1990s. Nutrient inputs from land are decreasing. Phytoplankton biomass is decreasing in most parts of the Wadden Sea. Green algal mats on intertidal flats have never again reached the massive coverage of the early 1990s, and seagrass beds are recovering. In spite of this, total nitrogen concentrations in rivers debouching into the Wadden Sea are still about 7–8 times higher than the assumed background values, and estuaries have lost most of their primordial filter and retention capacity.

In contrast to coastal regions with more stagnant waters, strong water currents and waves in the Wadden Sea have prevented large-scale oxygen deficiencies. Instead, benthic suspension and deposit feeders were supplied with more food than

there would have been without eutrophication. Predation by juvenile shrimp and crabs on recruits of bivalves has limited their abundances in the lower intertidal zone. This predation pressure is particularly effective when winter conditions remain mild, leaving less prey for fish and birds. Other confounding effects have been exploitations of cockles and blue mussels. Increased numbers of introduced American razor clams, slipper limpets and Pacific oysters may take their place or enlarge the suspension feeder component. All of these introductions seem to be less accessible to predators than native molluscs. It is not known whether these introduced filter feeders have already affected phytoplankton biomass.

In a recreational area such as the Wadden Sea, the goods and services of an ecosystem are disproportionately measured by the abundance of large-sized or otherwise conspicuous consumer species. In the water there are no signs of recovery for once common sturgeon, salmon and rays. At the bottom, native oysters and reefs of sabelariid worms did not recover either. Most bird populations which were severely affected until the 19th century have benefited from cessation of egg collecting and hunting as well as from protecting breeding and roosting areas. This process of bird recovery is still under way for some bird species and also applies to seals. One may wonder how many top consumers the Wadden Sea ecosystem can provide with sufficient food.

While herbivorous birds seem to be on the safe side, there are indications that mollusc-feeding birds such as common eider, oystercatcher, knot and herring gull have suffered from food shortage, particularly in the Dutch Wadden Sea. It cannot be ruled out that this shortage has been caused by the mussel and cockle fishery. A further prob-

lem for mollusc-feeding birds may arise when recruitment failures in bivalves become more frequent as winters continue to be rather mild.

Whether a further reduction of nutrient supply will eventually result in food shortage for top consumers is unclear because of the many alternative pathways in the food web. Effects of the changed nitrogen-phosphorus ratio have not yet become apparent. Anyhow, anoxia or harmful algal blooms are not likely to increase under the present level of eutrophication.

14.7 Conclusion

The present Wadden Sea is a particular habitat problem area and still deficient in a number of charismatic species which once lived in this re-

gion. This is mainly the result of various pressures exerted by human activities. Relevant issues for the future are also an increasing impact of introduced species, the consequences of sea level rise and an assumed trend towards sandier sediments. Precaution requires the further reduction of the release of technogenic toxic substances and the prevention of the release of novel ones. The need for balancing the reduction of nutrient enrichment deserves to be critically assessed. Future management of the natural values of the European Wadden Sea should be better tuned to the apparent differences between subareas as well as taking into account the cross-boundary relationship between this system and the influences from large river catchment and offshore areas.

15. Target Assessment and Recommendations

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15.1 Introduction

In this final chapter, a general evaluation and assessment is given, mainly based on the material presented in chapters 4 to 13. As in the 1999 QSR, this chapter is structured according to the habitats as entailed in the Wadden Sea Plan with added sections on chemical quality of the Wadden Sea system, on introduced species, birds and on marine mammals.

In each of the sections below, the main findings presented in this report are summarized. This is followed by one or more conclusions, which also give information regarding the status of the various trilateral Targets formulated in the Wadden Sea Plan. Finally, recommendations are formulated, relating to policy and management, monitoring and the need for further research.

An assessment of the status and development of the Wadden Sea ecosystem and the trilateral targets would not have been possible without the Trilateral Assessment and Monitoring Program (TMAP) and additional national and international programs. Therefore, no recommendations are presented regarding the necessity of continuation of the TMAP as it is.

The TMAP covers the entire Wadden Sea area including islands and offshore areas and spans a broad range from physiological processes through population development to changes in landscape and geomorphology. Furthermore, the TMAP considers the EC Birds and Habitats Directives, as well as other international obligations, such as the Ramsar Convention, the Bonn Convention, and the OSPAR Convention, and contributes to a great extent to the monitoring obligations of the EC Water Framework Directive.

The TMAP consists of a 'Common Package' of parameters which provides an appropriate basis of information concerning the most important questions to be addressed in the protection and management of the Wadden Sea. A process to optimize the TMAP and further tune it to the re-

quirements of the EC Water Framework, Birds and Habitats Directives is presently ongoing.

For the compilation of this QSR, for the first time an operational common TMAP data exchange system was used.

15.2 Quality of water, sediment and biota

15.2.1 Nutrients and eutrophication

A study on Wadden Sea specific eutrophication criteria carried out in 2001 and based on data up to 1996 suggested that the Wadden Sea is nitrogen limited and not phosphorus limited. Based on the OSPAR Comprehensive Procedure, the study suggested that autumn concentrations of ammonia and nitrite were suitable indicators of the eutrophication status of the Wadden Sea.

Up to 2002, riverine input of nutrients continued to decrease. In the Wadden Sea, this led to further decreasing phosphate concentrations in winter. Although the winter concentrations of nitrate and nitrite decreased in the German Bight, no consistent trend is discernable yet inside the Wadden Sea. This may indicate that the evaluation procedure as used in this and previous QSRs is not able to resolve the decreasing trend. The decrease in riverine nutrient input caused a similar trend in phytoplankton chlorophyll levels in summer in most of the southern Wadden Sea and in the Sylt/Rømø area. Chlorophyll levels show spatial differences, with the southern Wadden Sea having levels about twice as high as the northern Wadden Sea. Also near the major nutrient sources (Rhine-Lake IJssel, Elbe) higher levels occur.

Blooms of toxic and nuisance algae continued to occur, but did not increase. Dutch monitoring of the Marsdiep tidal inlet revealed a decrease in the duration of *Phaeocystis* blooms. Severe negative effects of toxic blooms were not observed, although the harvest of shellfish fishery was affected to some extent and some fish kills occurred along the Danish coasts.

Green macroalgae, consisting of several systematic groups, showed a general decline. In the summer of 2004, coverage of tidal flats went back to low values as observed prior to about 1980. Although massive development of green macroalgae is often related to coastal eutrophication, the developments in the Wadden Sea cannot be clearly linked to changes in nutrient input, remineralization rates or other environmental conditions.

The results of the 2001 study, that autumn concentrations of ammonia and nitrite are suitable indicators for organic matter turnover and eutrophication, were confirmed for the southern Wadden Sea (Netherlands, Norderney area). In the northern Wadden Sea, the ammonia and nitrite levels are about twice as low as in the southern part and are in line with a lower eutrophication status of the northern Wadden Sea as indicated by the summer chlorophyll levels.

Target

A Wadden Sea which can be regarded as a eutrophication non-problem area.

Target evaluation

- Though nutrient concentrations have decreased, the entire Wadden Sea still has to be considered a eutrophication problem area, meaning that the target has not yet been met.

Conclusions

- Riverine nutrient inputs have decreased gradually, resulting in decreasing phosphate concentrations. The Wadden Sea ecosystem, at least some parts of it, showed its response: decreased chlorophyll levels and lower organic matter turnover. No significant decrease, however, was observed of nitrogen concentrations inside the Wadden Sea in winter;
- Riverine nitrogen concentrations are still 7–8 times higher than riverine background concentrations for total nitrogen;
- The present organic matter turnover, as indicated by the concentrations of ammonia and nitrite, is about 3 to 5 times higher than under eutrophication non-problem conditions;
- Regional differences observed indicate a more intense eutrophication in the southern as compared to the northern Wadden Sea.

Recommendations

- In order to meet the target, continued effort is necessary to effectively implement current policies to reduce nutrient inputs; special ef-

fort is necessary with regard to nitrogen compounds;

- The temporal and spatial resolution of monitoring should be adapted to better cover the algal growth season and the whole annual cycle;
- Development of a harmonized approach for determining water residence time in different parts of the Wadden Sea to enable proper assessment of observed nutrient concentrations;
- Research should be done with priority into 1) the causes of the observed differences in eutrophication status between different parts of the Wadden Sea, and 2) the role of suspension feeders, including the Pacific oyster and the American jack-knife clam in the chlorophyll dynamics when using chlorophyll as indicator of eutrophication;
- Further research is necessary to assess how fundamental processes, e.g. nutrient regeneration from organic matter in the sediment, oxygen dynamics and food-chain effects respond to decreasing nutrient input.

15.2.2 Hazardous substances

Riverine inputs, as well as concentrations in sediment, blue mussels, flounder and bird eggs of metals and xenobiotics were presented and analyzed for the period 1985 to 2002 inclusive. Input from the River Rhine was included because of its impact on the Wadden Sea system. Data about polyaromatic hydrocarbons (PAHs) was not part of the TMAP Common Package. Evaluations were made for different subareas of the Wadden Sea as in the 1999 QSR.

15.2.2.1 Natural micropollutants (metals, PAHs)

The general picture is that in the period 1996–2002 metal input via rivers and concentrations of metals (Cd, Cu, Hg, Pb, Zn) in the Wadden Sea remained at more or less the same level as in 1995 or continued to decrease at a moderate rate. Significantly higher river loads in 2002, however, were recorded in the Elbe for cadmium, copper, and zinc, this being related to a significantly higher water discharge. A similarly enhanced river load in 2002 in the Weser was recorded for mercury and zinc. In decreasing order of importance, Elbe, Weser and Lake IJssel, still are the three quantitatively most important contributors of metals to the Wadden Sea. Atmospheric input of metals amounts to no more than a few percent of the summed riverine input.

Riverine input of polycyclic aromatic hydrocarbons (PAHs) is not well known. Atmospheric deposition in the Dutch Wadden Sea in 2000–2001 was estimated at about 800 kg per year. Concentrations in sediment were taken from the OSPAR Joint Assessment and Monitoring Program (JAMP).

In sediment, concentrations of the 6 PAHs of Borneff did not show any trend in the Dutch Wadden Sea since 1988. The same applies to the little available German and Danish data.

Concentrations of mercury and lead exceeded proposed background concentrations. For zinc this was the case only in subarea DK1. Concentrations of mercury, copper and cadmium did not exceed the ecotoxicological assessment criteria developed by OSPAR (2004). Zinc concentrations equalled the higher limit, and lead concentrations even surpassed the limit of the OSPAR ecotoxicological assessment criteria.

In blue mussels, concentrations of cadmium, copper, mercury and lead exceed the proposed background values.

In flounder, elevated concentrations of cadmium and mercury in subarea SH1 are considered indicative of the extreme River Elbe flood in 2002.

In eggs of oystercatcher and common tern, mercury levels generally decreased further. Exceptions, however, are recently increased mercury levels in the western Dutch Wadden Sea and Elbe estuary, indicating local sources.

Target

Background concentrations of natural micropollutants in water, sediment and indicator species.

Target evaluation

- For metals in sediment, the target has not yet been reached in all subareas of the Wadden Sea; enhanced concentrations occur in areas influenced by river discharge;
- For four metals, concentrations in blue mussels do not yet meet target levels;
- Mercury in bird eggs does not yet meet target levels;
- Regarding ecotoxicological assessment criteria accepted by OSPAR, concentrations in the Wadden Sea of mercury, copper, cadmium and PAHs do not pose a risk to the ecosystem, but zinc and lead still do;
- For PAHs in sediment, no natural background level has been documented. Concentrations are lower than in the Skagerrak, and higher than in Barents Sea sediments.

Conclusions

- For metals, riverine input is quantitatively the most important input to the Wadden Sea;
- Input of metals continued to decrease or remained unchanged. In some years enhanced loads were due to high river discharge; for organic micropollutants no trend was evident;
- The River Elbe flood of August 2002 caused only a short-term and regional (SH1) increase of cadmium and mercury levels in flounder;
- Anomalous metal concentrations in sediment were found at two locations in subareas SH3 and DK2;
- Little progress has been made, either in JAMP or in TMAP, regarding harmonization of methodology of standardization and data quality control allowing reliable comparison of data.

Recommendations

- Continued attention on reduction of metal discharges through rivers debouching into the Wadden Sea;
- Continued effort regarding harmonization of methods of analysis and of standardization, both being necessary to enable reliable comparisons at a geographical scale;
- Investigate the reason of anomalous metal concentrations in sediment found at two locations in subareas SH3 and DK2;
- Nickel, being a high priority compound in both OSPAR and EC WFD, to be included in the TMAP Common Package and data units.

15.2.2.2 Man-made substances (xenobiotics)

Among the xenobiotics monitored in the TMAP are PCBs (polychlorinated biphenyls), organotin compounds (e.g. TBT, TPT), hexachlorobenzene (HCB), Lindane (γ -HCH) and other pesticides. Organotin compounds in water of Dutch marinas decreased by ~60% between 1990 and 2002.

Riverine input of the above mentioned xenobiotic compounds generally continued to decrease. An exception is the increase of Lindane concentrations due to temporarily (1996 till 2000) increased input by the Elbe, the source of which is not known. One new element is the observation of relatively high concentrations of the biocide triphenyltin (TPT) which is known to be used for potato crops.

The persistency of most xenobiotics still constitutes an environmental problem as old deposits may be remobilized and transported to the Wadden Sea. The Elbe flood of August 2002 caused

an increase of DDT and DDE levels in blue mussels in subarea SH1.

Contents in sediment of PCBs had decreased in subarea NL1, as a result of which the gradient of decreasing concentrations from west to east had disappeared. Also for HCB, sediment concentrations decreased in the Dutch Wadden Sea, the lower values being at comparable level with concentrations in the Danish Wadden Sea. Organotin contents in the Dutch Wadden Sea decreased, but the high OSPAR ecotoxicological assessment criteria were still exceeded in 2002.

In blue mussels, contents of total PCBs, though highly variable, suggest a downward trend. In the northern Wadden Sea this decreasing trend was significant. Concentrations do, however, exceed the OSPAR background range. Ecotoxicological assessment criteria (OSPAR) are met only in Denmark. Lindane concentrations have decreased, now being at the same low level everywhere in the Wadden Sea. DDT/DDE concentrations also decreased. The Elbe flood of 2002 caused an increase in subarea SH1. For HCB, former 'hot spots' in subareas NL3 and SH1 have disappeared. Locally, enhanced concentrations are still found. TBT and TPT are dominant organotin compounds. In 2002 the OSPAR ecotoxicological assessment criteria were exceeded in the Dutch Wadden Sea.

In flounder, concentrations of PCBs have not really continued to decrease in the last 5 years. Highest levels were recorded in subareas NL1 to SH1. Adult flounders exceeded the OSPAR ecotoxicological assessment criteria. Lindane concentrations were very variable, showing a clear decrease only in subarea SH1. In 2002, highest concentrations were recorded in subareas NL1 to NDS3; here also the OSPAR ecotoxicological assessment criteria were exceeded. DDT and metabolites were variable, but high in subareas NDS2 and SH1. Former 'hot spots' of HCB contaminations in flounders in subareas NL3 and SH1 had disappeared. Increased concentrations due to the Elbe flood of 2002 were noted. The geographical variation of concentration levels, with the lowest present in subarea DK3, suggests that historical and local contamination exists mainly in the central and western part of the Wadden Sea.

In harbour seals found dead during the PDV-epizootic in 2002, and in common eider found dead during the winters of 1999 and 2000, very high organotin concentrations were found, indicating strong biomagnification. The effects of these compounds are largely unknown.

In eggs of oystercatcher and common tern, levels of PCBs and organochlorines have further de-

creased, especially in the Elbe area. Local sources of contaminants, however, can still be discerned through elevated levels in the vicinity of Rhine/Lake IJssel, Ems and Elbe.

Newly emerging xenobiotics, such as brominated flame retardants, perfluorinated octane sulfonates (e.g. PFOS), Irgarol (anti-fouling agent), alkylphenoles, Bisphenol-A and phthalates, none of which are part of the TMAP Common Package, were found to occur in various compartments of the Wadden Sea ecosystem. The ecotoxicological effects of some of these compounds are not well known.

In addition to PCBs and tributyltin (TBT), many other compounds have proven to be or are suspected of causing disruption of hormone-regulated endocrine processes in marine animals. Many of these hormone disruptors have been demonstrated to occur in the Wadden Sea, but so far there is little indication of hormonal disruption among fish and invertebrates, in contrast to findings in estuarine and coastal waters in the UK and the southern Baltic Sea.

Bioassays, Effect Directed Analysis (EDA) and Toxicity Identification Evaluation (TIE) have been developed as biological effect assessment techniques to assist the management of various discharges into the environment and the identification of culprit chemicals. These techniques are not yet commonly used in the Wadden Sea.

Target

Concentrations of man-made substances as resulting from zero discharges.

Target evaluation

- Although for a number of xenobiotic compounds discharges to and concentrations in the Wadden Sea have decreased, the target has not yet been reached;
- For some substances, e.g. TPT and Lindane, a significant deviation from the target is apparent;
- For PCBs, Lindane and TBT, the OSPAR ecological assessment criteria are exceeded in various Wadden Sea subareas;
- Of many newly developed xenobiotics, including hormone disruptors, concentrations have been found in the Wadden Sea, which is a deviation from the target;

Conclusions

- Further reduction has occurred of riverine discharges and of environmental concentrations,

however, with exceptions for certain compounds and localities;

- The ban on the use of anti-fouling paints containing organotin for pleasure craft showed its effect in decreasing contamination of Dutch marinas;
- PCB-levels still exceed agreed background levels;
- Many newly developed xenobiotics, including hormone disruptors, have a wide occurrence in the Wadden Sea ecosystem, but are not included in the TMAP Common Package;
- Progress has been made in the development of biological effects assessment techniques.

Recommendations

- Extra attention to be paid to some recently and locally increased contaminant concentrations and to the sources of triphenyltin;
- Ecotoxicological research into the effects of organotin accumulation in common eider and harbour seal;
- Inclusion in TMAP of priority substances among the newly developed xenobiotics and hormone disruptors in connection with the requirements of the EC Water Framework Directive;
- Trilateral application of biological effects assessment techniques (e.g., bioassays, EDA, TIE) as a management and monitoring tool.

15.2.3 Oil pollution and seabirds

The main source of oil pollution at sea is illegal discharges with fuel oil residues due to operational processes on board ship, causing a clustering of oil slicks around the major shipping lanes. The number of oil spills reported along the Dutch and German coasts have decreased as compared to the 1990s. This kind of chronic oil pollution is a constant threat to seabirds. Surveys of birds found dead on the beaches, and an assessment of the proportion of these birds contaminated with oil, has been used as an indicator of oil pollution from shipping in the Wadden Sea and in the coastal waters of the North Sea. A large proportion, sometimes even 90%, of birds washed onto the beaches have been contaminated with oil.

In 1997, the North Sea was designated as 'Special Area' under the MARPOL Convention Annex I. The designation in 2002 of the Wadden Sea as a Particularly Sensitive Sea Area (PSSA) by the International Maritime Organization (IMO) was a further step to increasing awareness of the particular sensitivity of the Wadden Sea Area to impacts from shipping, such as oil pollution.

In the 1999 QSR, declining oil rates among beached birds were seen as a clear signal that the situation was improving. Since then, rates have declined further, but are still high. Oil rates among birds found inside the Wadden Sea are lower than those among birds found stranded on the North Sea beaches of the Wadden Sea islands. Increased oil rates, however, were established in The Netherlands in the winters 2002/03 and 2003/04, probably due to ship accidents such as those of the 'Tricolor' and 'Assie Eurolink'. It is too early yet to observe any effect of the designation of the PSSA 'Wadden Sea'.

Within OSPAR, an Ecological Quality Objective (EcoQO) regarding oil pollution at sea was developed for the common guillemot, a common seabird of the North Sea. In the Wadden Sea area, an oil rate of 10%, which is the EcoQO for the common guillemot, has still not been reached, despite an overall decline in oil rates since the mid-1980s. Shelduck, common eider, and herring gull, species more representative for the Wadden Sea area than the common guillemot, showed lower oil rates in 1999–2003 as compared with earlier periods.

Target

No specific target was formulated with respect to the effect of oil pollution on seabirds. As an alternative, the Ecological Quality Objective (EcoQO) developed by OSPAR was applied:

The proportion of oiled common guillemots among those found dead or dying on beaches should be 10% or less.

Target evaluation

- For common guillemot, the OSPAR Ecological Quality Objective (EcoQO) of 10% oil rate has not been met.

Conclusions

- Reported oil spills off the German and Dutch coast declined in comparison to the 1990s;
- Oil rates among beached birds have generally decreased further, but are still high. In the last few years, however, oil rates were found to have increased again in the Netherlands;
- Oil rates among birds inside the Wadden Sea are lower than on the North Sea beaches of the Wadden Sea islands.

Recommendations

- Continuation and further implementation of policies and measures to prevent oil pollution, including education programs for seafarers;

- Continued and well coordinated trilateral monitoring of beached birds is required to be able to assess the effect of the PSSA designation, and of North Sea wide oil pollution control policy;
- Analysis of oil residues on beaches and oiled birds washed ashore to be used to monitor the effectiveness of pollution control measures aimed at reduction of oil pollution from different sources.

15.3 Salt marshes

For salt marshes, three different targets apply, relating to (a) total area, (b) natural geomorphology and dynamics and (c) natural vegetation structure.

A fourth salt-marsh target 'Favorable conditions for migrating and breeding birds' will be addressed in section 15.8.

15.3.1 Area of natural salt marshes

Natural salt marshes with an undisturbed geomorphology, vegetation and dynamics are characterized by the presence of meandering creeks, a diverse vegetation reflecting a diversity in sediment type and elevation, and no impact from human use and erosion protection measures.

Natural salt marshes occur mainly in sandy back-barrier conditions (e.g. on the barrier islands) whereas most of the mainland salt marshes are artificial because geomorphology is strongly affected by humans. Semi-natural salt marshes have developed within man-made sedimentation fields with a man-made drainage system or are affected by grazing or cutting.

In The Netherlands and Germany, roughly 57% of the salt marshes on the islands, and roughly 7% of the salt marshes on the mainland, have never been artificially drained and are not grazed by livestock and thus can be regarded as natural. For Danish salt marshes detailed figures on drainage and grazing were not available for GIS analysis.

A general increase of the total salt marsh area has been observed in most parts of the Wadden Sea during the past decades. This, however, includes all types of salt marshes. A more precise statement regarding the increase of area of natural salt marshes is hampered by the fact that accurate data about geomorphology, vegetation, drainage and grazing has become available only in the last few years. A direct comparison with data presented in the 1999 QSR cannot be made because this data did not include the pioneer zone or consisted of estimations and therefore did not comply with the recently developed standard methods.

An increase of the area of (semi-)natural salt marshes may take place through de-embankment of summer polder. Currently, a total of about 620 ha (240 in Niedersachsen, 40 Hamburg, 340 in the Netherlands) has been or will be de-embanked. The results of recent de-embankment projects showed that restoration of a natural salt marsh situation may take several years or decades depending on the geomorphological and hydrological conditions.

Target

An increased area of natural salt marshes.

Target evaluation

- In most parts of the Wadden Sea, an increase in area of natural and semi-natural salt marshes could be observed. An evaluation of the target in quantitative terms is, however, not possible for the entire area because of insufficiently detailed older data.

Conclusions

- About 56% of the island salt marshes in The Netherlands and Germany can be regarded as natural salt marshes;
- In those areas of the Wadden Sea where long-term data is available, an increase in salt marsh area (natural as well as semi-natural salt marshes) has been observed over the past decades. Locally, mainly at non-sheltered places along the mainland, losses have occurred due to erosion;
- An increase of the area of salt marshes could be achieved by de-embankment of summer polders. In due course, these marshes will develop to salt marshes with a more natural vegetation structure.

Recommendations

- Further development of naturally growing salt marshes is best helped by leaving geomorphology of neighboring mudflats undisturbed;
- Further increase of area of (semi-)natural salt marshes can be achieved by breaching protecting summer dikes or sand dikes;
- For vegetation mapping of de-embanked polders and other study sites, a frequency should be chosen tuned to the velocity of the salt-marsh development process.

15.3.2 Increased natural morphology and dynamics of artificial salt marshes

In artificial (*i.e.* man-made through land reclamation) salt marshes mainly located along the main-

land coast artificial drainage systems have been used extensively in the past. During the last two decades the use of artificial draining has been significantly reduced, which has resulted in a more natural situation.

In about 34 % of the mainland salt marshes, no drainage measures have been taken during the past 10 years and 16% have never been drained artificially. In about 54% of the island salt marshes there were no drainage measures at all, and in an additional 34% of the island salt marshes no artificial drainage measures have been carried out during the past 10 years.

Long-term monitoring revealed that the artificial ditch systems were very persistent. The development of remaining ditch systems into natural-like creeks will probably take several decades.

Target

An increased natural morphology and dynamics, including natural drainage patterns, of artificial salt marshes, under the condition that the present surface is not reduced.

Target evaluation

- Artificial draining in salt marshes has been reduced. The remaining ditch systems, however, have not yet developed into natural-like creek systems.

Conclusion

- Reduction or cessation of artificial drainage has increased the natural geomorphology and dynamics of artificial salt marshes,
- The maintenance of artificial drainage systems in salt marshes has decreased significantly during the last two decades. In 34% of the mainland salt marshes no drainage measures have been carried out during the last 10 years, in addition to about 16% of salt marshes which have never been drained artificially.
- Development of artificial drainage systems into a natural-like creek system is a slow process which will probably take several decades.

Recommendation

- Cessation of artificial drainage in all salt marshes without any agricultural use, taking care of prevention of water logging of dike foots,
- Further study and experiments into effective ways of facilitating the development of natural-like drainage creeks.

15.3.3 Improved natural vegetation structure of artificial salt marshes

The 'naturalness' of the vegetation structure of artificial salt marshes strongly depends on the local geomorphological conditions, including existing sea dikes. A precise description of the vegetation that can develop, and that can serve as an evaluation criterion, could therefore not be formulated. In those salt marshes, a more diverse vegetation structure reflecting the geomorphological conditions can be reached by reduction of artificial drainage and livestock grazing.

In some areas, grazing has continued as a management tool for nature conservation aimed at maintaining short vegetation attractive to migrating geese and to creating heterogeneity of vegetation structure. In areas where salt marsh dynamics are hampered, for example because of the stabilization of sedimentation fields, mid and high-marsh communities may extend and vegetation may develop towards a dominance of few species. This ageing of salt marshes is a recent focus in research. In such salt marshes, moderate livestock grazing may result in high variation of the vegetation structure if this is aimed at.

Since the 1980s, livestock grazing has generally decreased in the entire Wadden Sea area. The reduction of 50% of areas with intensive grazing took place on the mainland salt marshes in the Netherlands and Germany. In Denmark, the situation has not changed much compared to about 75% intensive grazing on the mainland, and 10% on the island marshes in 1987. In the Northern Danish Wadden Sea, the proportion of intensively grazed areas increased from 30% (in 1989) to 40% (in 2000).

The development of the vegetation structure, also with regard to ageing of salt marshes, can now be better monitored in the entire Wadden Sea by using a newly developed common TMAP typology for salt-marsh zones and vegetation types.

Target

An improved natural vegetation structure, including the pioneer zone, of artificial salt marshes.

Target evaluation

- A precise evaluation of the target cannot be given, because long-term data is only available for some regions and the developed common typology could not be applied to older data. Significant reductions of livestock graz-

ing intensity in The Netherlands and Germany contributed to a more natural vegetation structure of artificial mainland salt marshes. In Denmark, the proportion of intensively grazed salt marshes did not really change.

Conclusions

- Human use (livestock grazing, cutting) of salt marshes has generally decreased; this has resulted in a more natural vegetation structure of artificial salt marshes;
- Livestock grazing is still used as a management tool aimed at making salt marshes attractive to specific birds species, and to creating heterogeneity of the vegetation structure;
- Natural development of salt marshes is limited by existing sea dikes and reduced natural sedimentation areas;
- In some areas, ageing of salt-marsh vegetation could be observed, characterized by mid and high-marsh communities. This ageing of vegetation will be retarded by livestock-grazing;
- The within TMAP developed common vegetation typology will facilitate a Wadden Sea wide harmonized assessment of salt-marsh development.

Recommendations

- To prepare a Wadden Sea wide assessment of salt-marsh vegetation development, based on the now available common vegetation typology, which also can be used for the requirements of the EC Habitats Directive;
- Study of the possible interrelationship between ageing towards climax vegetation, rate of sedimentation and cessation of grazing;
- Continuation of long-term study sites and incorporation of these sites into the International Long-Term Ecological Research sites (ILTER).

15.4 Tidal area

The trilateral Targets related to the Tidal Area of the Wadden Sea have a physical as well as a biological dimension.

15.4.1 Hydrology/geomorphology

A natural dynamic situation with respect to hydrology and geomorphology would imply no human interference in the shape and depth of tidal channels, as done by maintenance dredging of shipping channels, no artificial fixing of heads of islands to combat unwanted erosion, no sand nourishments of beaches and foreshore, and no

sediment disturbance by suction dredging cockle fishery. This would also imply the absence of disturbance of habitat forming biota, such as eelgrass beds and mussel beds (both intertidal and subtidal).

Tidal inlets and outer deltas are characterized by great natural dynamics. Positions of tidal channels, shoals and emerging sand banks are changing continuously.

For economic reasons, access to harbors in the Wadden Sea and its estuaries needs to be maintained. Keeping tidal channels and other shallow areas to a minimum depth required for safe shipping causes a continuous or periodic deviation of the natural and dynamic hydro-morphological equilibrium of the Wadden Sea system. Sedimentation-erosion processes make the system return to its equilibrium, causing renewed human intervention.

In the estuaries, an increase of the minimum depth in shipping lanes has led to an increased tidal regime causing higher high water levels, lower low water levels and higher tidal current velocities. It is not well known to what extent this has caused changes in the amount and nature of tidal flats and subtidal areas, although basic data may be available, for example, in the form of periodic sounding charts. Hypsometric curves, and temporal changes therein, might be useful as indicators of the geomorphological dynamics of estuaries and tidal basins.

Sea level rise due to climate change and progressive endikement and land reclamation have made the Wadden Sea narrower at many places. This, through increased wave energy, has led to a general depletion of fine-grained material and to a significant decrease of high mud flats bordering the mainland which constitute the preferred settling space for juvenile bivalves. These high mud flats are important as a settling habitat for juvenile bivalves. It is plausible that the intensive fishery for cockles and seed mussels in the Dutch Wadden Sea has contributed to a reduction of such high intertidal mud flats.

Target

1. A natural dynamic situation in the Tidal Area;
2. An increased area of geomorphologically [and biologically] undisturbed tidal flats and subtidal areas.

Target evaluation

1. The Tidal Area of the Wadden Sea is still characterized by a high degree of natural dynamics. There is no significant increase of construc-

tions for coastal defense. Deviations from Target 1 are existing coastal defense structures and deepening of channels for shipping;

2. Target 2 cannot be evaluated due to absence of proper information.

Conclusions

- Estuaries giving access to major sea ports (Elbe, Weser, Ems) experience progressive deepening causing hydrological changes. Also shipping channels adjacent to intertidal flats are deepened. It is not well documented to what extent these changes affect the target of geomorphologically and biologically undisturbed intertidal flats and subtidal areas (see also 15.6);
- Long-term sea level rise and land reclamation have caused loss of area of high mud flats, important as a settling habitat for juvenile bivalves.

Recommendations

- For a better assessment of the targets, parameters need to be developed within the TMAP to properly monitor changes in hydro-morphological dynamics and in geomorphologically and biologically undisturbed tidal flats and subtidal areas;
- A study should be undertaken into the effect of increased deepening for shipping on estuarine geomorphology, especially regarding changes in the amount and nature of tidal flats and subtidal areas;
- The signalized loss of high mud flats essential for bivalve settlement should be given more attention, through either monitoring or directed research.

15.4.2 Macrozoobenthos

Over the last 15 years, bivalve recruitment success has declined. This was accompanied by a shoreward shift of their centers of distribution, which is attributed to increasing predation pressure on the newly settled post-larvae by shrimps and shore crabs, and coincides with the occurrence of mild winters. This indicates the power of climate factors in governing recruitment, and therefore population sizes, of bivalves in the Wadden Sea. Continued global warming may therefore cause bivalve stocks to decline.

On a more regional scale, deterioration of sedimentary conditions may play a role, especially at the sandier lower tidal flats. Possible causes are removal of mussel beds by fishery and sediment disturbance by cockle dredging.

In general, mechanized fishery for cockles in the Dutch Wadden Sea has had negative effects on recruitment of cockles and non-target species living in intertidal flats. There is an indication that worms have increased in abundance. Mechanized cockle fishery in the Dutch Wadden Sea ceased on 1 January 2005.

During the last two decades the Wadden Sea has been in an early stage of eutrophication, almost without occurrence of harmful anoxia except in local 'black spots' and under patches of green algae.

Isolated populations of benthic invertebrates in estuarine and brackish habitats may be endangered. These populations need further attention in order to elucidate their status.

Target

An increased area of [geomorphologically and] biologically undisturbed tidal flats and subtidal areas.

Target evaluation

- The observed decline in bivalve recruitment and shift in their centers of distribution indicates a loss of previously biologically undisturbed tidal flats, in other words: a deviation from the target.

Conclusions

- Bivalve recruitment has declined and their centers of distribution shifted, largely due to increased epibenthic predation as a result of a series of mild winters; deterioration of sediment conditions due to shellfish fisheries may have contributed;
- A continued overall increase of worms was observed, the underlying cause of which is not well understood;
- Isolated populations of benthic invertebrates in estuarine and brackish habitats may be endangered.

Recommendations

- Elucidation of the status of isolated populations of benthic invertebrates in estuarine and brackish habitats, and of the underlying cause of the long-term increase in polychaetous worms and of shifting centers of bivalve recruitment.

15.4.3 Biogenic structures

Three species occurring in the Tidal Area of the Wadden Sea, *viz.* the seagrass *Zostera* spp., the blue mussel *Mytilus edulis* and the polychaetous

worm *Sabellaria spinulosa*, are responsible for the formation of specific biogenic structures. For these species a target applies regarding area and distributions of these structures.

Sabellaria reefs

Sabellaria-reefs are still extremely rare in the Wadden Sea, with only three known occurrences, viz. two in the Jade near Wilhelmshaven and one south of the island Amrum. The size of these reefs and their development over time are not well documented. This is partly caused by absence of systematic monitoring of these reefs (not included in TMAP Common Package), and partly by apparent inadequacy of the different methods used to survey the reefs.

Sabellaria reefs are placed on the Red List of Biotopes. Under the EC Habitats Directive (Annex I), conservation of reefs is required, and within the NATURA 2000 network *Sabellaria* reefs can be protected as Special Area of Conservation (SAC).

Target

An increased area of, and a more natural distribution and development of [natural mussel beds,] *Sabellaria* reefs [and *Zostera* fields].

Target evaluation

- No increased area of *Sabellaria* reefs has been reported.

Conclusions

- The dramatic decline of *Sabellaria* reefs has not stopped. Information concerning existing reefs is unsatisfactory;
- Specific measures to better protect existing *Sabellaria* reefs have not been implemented.

Recommendations

- The *Sabellaria* reefs should be designated as Special Area of Conservation, where especially seabed disturbing activities (sand extraction, dredging, bottom trawling) are not allowed;
- Human interventions changing the water current conditions should be considered carefully as they may affect *Sabellaria* reefs;
- A program should be launched under the TMAP to properly monitor existing *Sabellaria* reefs, and to explore the occurrence of reef structures in potential reef areas in the Wadden Sea Area. New reefs found should be considered for monitoring.

Seagrass (*Zostera* sp.) fields

In the southern and central Wadden Sea, the decline of seagrasses as observed between the 1950s

and 1990s seems to have come to a halt, and some slow recovery is evident. At present (2002/2003), seagrass beds with a total area of ca. 73 km² are distributed rather unevenly. Approx. 82% of the beds occur in the northern Wadden Sea between Eiderstedt and Skallingen where no long-term decline of seagrasses was noted. The total area covered has increased in The Netherlands and in Niedersachsen.

Both species *Z. marina* and *Z. noltii* show considerable interannual fluctuations in size and shape of local beds. Salinity and nutrient loading, separately and in combination, are important environmental factors for seagrass development. Local runoff of freshwater is considered advantageous for seagrass growth; these runoff points have been diminished by sea dike strengthening. Eutrophication and hydrodynamics seem to be the major factors determining the distribution of seagrasses in the Wadden Sea, while shellfish fishery and land reclamation have negative effects on a more local scale. Reintroduction programs, as performed in the western Dutch Wadden Sea, may have success in supporting the start of a natural recovery provided that the optimal locations are chosen.

Target

An increased area of, and a more natural distribution and development of [natural mussel beds, *Sabellaria* reefs and] *Zostera* fields.

Target evaluation

- The target of increased area of *Zostera* fields has not yet been met in all sub-regions of the Wadden Sea.

Conclusions

- It is still not precisely known how much *Zostera* occurs in the entire Wadden Sea and general trends in development can hardly be separated from more local phenomena and fluctuations;
- Although the long-term decline of seagrasses in the southern and central Wadden Sea seems to have come to a halt, and some slow recovery is evident in The Netherlands and Niedersachsen; no overall increase in area and natural distribution of seagrass fields has occurred;
- Reintroduction programs, if carefully designed, may contribute to seagrass recovery, especially in areas poor in natural propagules.

Recommendations

- Given the diminished and, in some areas, still

endangered state of seagrasses, negative effects of shellfish fishery and land reclamation works at existing and potential sites of seagrass beds should be avoided;

- Further reductions in nutrient loads would strengthen the vitality of seagrass when growing at average salinities;
- Restoring of ebb-sluches with continuous freshwater runoffs to explore their positive effects on local seagrass development;
- Further study of the effectiveness of re-introduction programs of intertidal seagrass, as well as a study of the feasibility of re-introduction of the large morph of *Zostera marina*;
- Improved harmonization of monitoring of and research into seagrass in the Wadden Sea.

Blue mussel beds

Intertidal mussel beds

As a follow-up of recommendations in the 1999 QSR, a protocol was developed for harmonized description and area measurement of intertidal mussel beds. In addition, in The Netherlands a habitat model was developed which is able to indicate where intertidal mussel beds are likely to develop and persist ('stable sites').

Introduced species such as Pacific oyster and slipper limpet may form a threat to existing mussel beds because these are effective competitors for space and food.

During the last 8-12 years, direct impact by fishery on the natural development of mussel beds in The Netherlands and Schleswig-Holstein has been small or absent. Restrictive fishery regulation as applied in The Netherlands contributed to reaching more than 2,000 ha of more or less stable mussel beds; few beds, however, developed in the western Dutch Wadden Sea. In the Danish Wadden Sea fishery had only local effects because of large closed areas. In Niedersachsen, the actual total area of mussel beds is below the level present in the late 1980s despite the recovery after the spatfall of 1996. Continued fishery led to loss of mussel beds. In response, 29 mussel bed sites have been protected from fishery since 2004.

Spatfall is a crucial process, the determining factors of which are still not well understood, especially those responsible for regional differences.

Subtidal mussel beds

Considerable areas of subtidal mussel beds exist in The Netherlands and Schleswig-Holstein, serving as an essential food resource for the common eider. These subtidal mussel beds are ecologically different from the beds in the intertidal, although

only limited information has become available on this issue. Mussel beds temporarily present on sublittoral culture lots are much poorer. Subtidal mussel beds are intensely exploited by fishermen, mostly for obtaining seed mussels to stock the culture lots. Because of their high biodiversity of associated fauna, subtidal mussel beds need to be better protected.

Target evaluation

Target

An increased area of, and a more natural distribution and development of natural mussel beds [*L. Sabellaria* reefs and *Zostera* fields].

- The target of an increased area of natural mussel beds in the intertidal area was reached in the mid and eastern Dutch Wadden Sea. In the Danish and western Dutch Wadden Sea, no development according to the target occurred. In Niedersachsen, the actual total area of mussel beds is below the level present in the late 1980s and in Schleswig-Holstein still below the level present in the early 1990s;
- With regard to the subtidal mussel beds, no evaluation of the target is possible yet.

Conclusions

- The new protocol for area measurement of intertidal mussel beds will enable a harmonized assessment of the target in future;
- The Dutch habitat model has proven to be a useful tool for the protection of intertidal mussel beds;
- Subtidal mussel beds may be heavily exploited by mussel farmers to obtain seed mussels for stocking their culture lots;
- Subtidal mussel beds may be characterized by a high biodiversity, but data is still scarce;
- Natural development of intertidal mussel beds occurred as a result of consecutive spatfalls and large areas having been without fishery for seed mussels; poor recruitment since 1999, however, has caused a decline;
- Progress was made with protection of young mussel beds at old (stable) sites of mussel beds.

Recommendations

- Research on the spatfall process in general, and on the cause of the regional differences in recruitment success;
- Because of their high biodiversity and ecological importance, a trilateral protection regime

should be designed for subtidal mussel beds; subtidal and intertidal beds should also be considered as a biological quality element in the relevant EC Directives;

- The proliferation of the Pacific oyster should be monitored, and its competitive mechanism leading to the taking over of mussel beds investigated, with a view of developing options for management;
- The management measure of protecting stable mussel beds or sites (intertidal as well as subtidal) is still valid;
- Extension – if possible – of the habitat model developed as a management tool for intertidal mussel beds in the Dutch Wadden Sea to the German and Danish Wadden Sea as well.

15.4.4 Introduced species

Regarding introduced species no targets have been formulated. Introduction of species from elsewhere to the Wadden Sea can hardly be controlled, as these can reach the Wadden Sea using natural vectors (e.g. sea currents) as well as anthropogenic vectors, such as tanker ballast water and transport of aquaculture products. Control will never be 100% effective. Moreover, climatic change due to global warming will allow species with a more southerly (or warmer) geographic distribution to establish populations in the Wadden Sea.

So far, there are only few examples of introduced species in the Wadden Sea that have had a negative impact on resident populations. Cord grass (*Spartina anglica*) displaced seagrass locally and the Pacific oyster (*Crassostrea gigas* – also known as Japanese oyster) currently seems to be taking over blue mussel (*Mytilus edulis*) beds. In both instances one can argue that a new biocoenosis is formed, which in the case of the Pacific oyster may be of high biodiversity. A single introduced species, however, may be able to cause severe ecological change, economic damage or be a threat to human health. Therefore, adaptations of TMAP may be necessary in order to provide the data for evaluating the possible impact of introduced species.

Target

(With respect to introduced species, no target was formulated).

Target evaluation

- Not applicable.

Conclusion

- Once they are established in the Wadden Sea, it is not easily feasible to effectively prevent further spreading of species, or to control their population development. Any action to remove an introduced species from the Wadden Sea would inevitably do harm to other components of the ecosystem;
- Effects of introduced species on the Wadden Sea ecosystem are difficult to predict.

Recommendation

- The TMAP should be alert to discover new immigrant species, and may need to be adapted to provide data for impact assessment of introduced species;
- Consider appropriate precautionary measures to prevent further introduction of species that may constitute a risk to the Wadden Sea ecosystem;
- Study of the ecological function of the newly developing reefs of Pacific oysters.

15.4.5 Fish and shrimps

No trilateral targets have been formulated with respect to the fish and shrimp fauna of the Wadden Sea and its estuaries. Neither have specific parameters been included in the TMAP Common Package.

Brown shrimps play an important role in the Wadden Sea food web. They are epibenthic predators of small and juvenile zoobenthos and in turn serve as food for birds, fish and young seals. There is a fishery for brown shrimp in the Wadden Sea and the adjacent coastal zone of the North Sea.

Fish species use the Wadden Sea for different purposes. Some species, called residents, live here all their life; for others, it is just for passing through during their migrations between breeding habitats in freshwater and adult habitat in the sea, or vice versa. For a number of North Sea fish, e.g., the flatfish species plaice and dab, the Wadden Sea is important as a nursery; larvae enter the Wadden Sea, recruit to benthic life and profit from the available food resources before rejoining their adult populations in the North Sea. Depending on their occurrence mainly near the bottom or higher in the water column information has become available from national demersal fish surveys and local pelagic sampling programs.

Target

No specific fish-related trilateral targets have been formulated. The following more general targets do have some relationship:

1. An increased area of geomorphologically and biologically undisturbed tidal flats and subtidal areas;
2. A favorable food availability [for migrating and breeding birds].

Target evaluation

1. The target of undisturbed tidal flats and subtidal areas for fish and shrimp cannot be evaluated. The possibility of the observed shift in juvenile flatfish being related to a decreased area of undisturbed tidal flats and subtidal areas needs to be investigated;
2. There is currently no evidence of food shortage among fish and shrimp eating birds.

Conclusions

- Though demersal fish surveys are being carried out in all three Wadden Sea countries the methodology used is not well harmonized. For pelagic fish, information is fragmentary due to the absence of appropriate monitoring;
- The numbers of juvenile flatfish using the Wadden Sea as a nursery are clearly declining. This is especially so for dab and plaice, and is due to an offshore shift in the distribution of these fish species along the North Sea coast;
- The abundance of diadromous fish species is still low.

Recommendations

- The formulation of trilateral targets regarding fish, tuned to the requirements of the relevant EC Directives, will structure and focus research and monitoring of this important faunal group in the Wadden Sea;
- The existing demersal fish survey programs should be trilaterally coordinated and harmonized to provide valuable information on the quality of the Wadden Sea as a habitat for demersal fish;
- Development of trilaterally coordinated pelagic fish monitoring program, especially aimed at obtaining data about fish species depending on upstream water quality and breeding habitat;
- Studies should be undertaken to improve the ecological knowledge of non-commercial species, to investigate the functional relationship between fish species and specific habitats such as mussel beds and other hard substrate, and to obtain insight in the factors underlying the shift in distribution in juvenile flatfish;

- For threatened diadromous fish species further conservation effort is required, e.g. sluice and dike passage facilities and upstream habitat restoration.

15.5 Beaches and dunes

With regard to beaches and dunes, targets apply regarding natural dynamics, natural vegetation succession and favorable conditions for migrating and breeding birds

Beaches

With respect to the beaches of the Wadden Sea islands, for the first time in the QSR information about their ecology is presented from national projects. No specific parameters have been made operational within the TMAP. The available information is limited and does not allow a complete assessment of the status of the Wadden Sea beaches. However, it was shown that different types of beaches (reflective vs. dissipative, eroding vs. accreting) each have their own characteristic meio- and macrobenthic fauna serving as food for fish and shore birds.

The natural dynamics of beaches are locally and periodically influenced by coastal protection measures, e.g. in the form of stony groynes and sand nourishment of the beach or foreshore. Coastal protection measures are expected to increase related to continued sea level rise. Dynamic upper parts of sandy beaches may provide an essential breeding habitat for birds like kentish plover and great ringed plover. The breeding success of these birds may suffer from human recreational activities unless proper protection measures are implemented (see under 15.8.2).

Dunes

Natural dynamics of beaches at head and tail ends of some islands have increased due to major reduction of coastal protection measures. In the dunes more centrally on the islands, however, dynamics have increased only locally. The area with embryonal dunes, white dunes and primary dune slacks has not increased. Remnant coastal defence structures such as sand dikes, act as limiting factor. Areas with free-blown sand are still very limited. About two thirds of the Wadden Sea dunes consist of mid-successional type vegetations, 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.

On some of the islands, species-rich dune slack vegetations have degraded due to groundwater extraction, causing an accelerated succession to drier communities.

Accelerated succession in dune vegetations is presently being remedied in some areas by application of traditional-style management measures, restoring successional processes and 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 have strongly declined due to the development of dense grass-dominated vegetations, partly due to airborne eutrophication. Increased scrub vegetation has led to the decline in numbers of some characteristic birds of prey.

- Target**
1. Increased natural dynamics of beaches, primary dunes, beach plains and primary dune valleys in connection with the Offshore Zone;
 2. An increased presence of a complete natural vegetation succession.
 3. Favorable conditions for migrating and breeding birds.

Target evaluation

1. The target of increased natural dynamics of beaches and dunes cannot be fully evaluated due to absence of criteria and of comparable relevant data; natural dynamics has increased where coastal defense activities were stopped; remnant coastal defense structures still remaining restrict increased dynamics;
2. A complete natural vegetation succession is not present because about two-thirds of the dune areas consists of mid-successional dune type and important other types are not present or show further decline;
3. The target 'Favorable conditions for migrating and breeding birds' will be evaluated in section 15.8.

Conclusions

- Too little information is available to allow a complete assessment of the status of the Wadden Sea beaches;
- No parameters have been developed within the TMAP to enable an evaluation of the target of (increased) natural dynamics of beaches;
- A major reduction of coastal protection measures has caused increased dynamics in beaches and primary dunes. Areas with free-blown sand, however, are still very limited;
- Eutrophication from atmospheric deposition has caused dense grass vegetations to devel-

op and on some of the islands, species-rich dune slack vegetations have degraded due to groundwater extraction;

- The use of traditional-style management measures can contribute to restoring successional processes and species-rich habitats.

Recommendations

- The trilateral targets with respect to beaches need to be reconsidered and redefined against the background of (1) sea level rise and concomitant intensification of coastal defense, and (2) increased recreational pressure on the coastline;
- A better exchange of information about how coastal protection measures and remnant sand dikes influence pioneer stages and the possibilities for restoring natural dynamics;
- An inventory of the differences in water extraction management and of their ecological consequences;
- Existing differences in dune management regimes make a case for exchange of information on this issue among managers involved;
- More fundamental studies of the speed and direction of natural succession under different conditions, with the aim of contributing to future policy and management questions concerning the Wadden Sea dunes;
- The use of the newly developed TMAP classification for dunes for trilateral assessment of dune development, and concurrent data collection concerning atmospheric deposition, coastal protection measures and water management.

15.6 Estuaries

With regard to estuaries, the targets relate to protection of valuable parts and to restoration of riverbanks.

No comprehensive overview could be given of developments of human pressures in estuaries, and of the related hydrological, geomorphological and ecological response. Water Framework Reports 2005, however, state that in transitional waters (= estuaries) of the Wadden Sea Area significant changes have occurred in hydrology and that there has also been a reduction of tidal flats and brackish marsh habitats.

In German estuaries, the Ems included, increased deepening through dredging to promote safe shipping access to ports has led to changes in the tidal regime. No geomorphological changes of any importance have been observed. In the Ems estuary continued siltation of one of the tid-

al channels raises the question of future policy: allowing the development of a 1-channel system or maintaining a 2-channel system as in the Western Scheldt (SW Netherlands)?

Monitoring of macrozoobenthic communities in German estuaries revealed that of the species found, only a minor part form a stable community. Nevertheless, these estuaries provide biotopes for a number of red list species, the extent of which is not well documented.

Target

Valuable parts of estuaries will be protected and river banks will remain and, as far as possible, be restored to their natural state.

Target evaluation

- According to Water Framework Directive Reports 2005, most estuaries in the Wadden Sea Cooperation Area fail to meet the target.

Conclusions

- Continued deepening of shipping channels in estuaries has led to changes in the tidal regime;
- Geomorphological changes in estuaries are not very clear, except for the continued siltation of the Bocht van Watum tidal channel in the Ems estuary;
- Progressive human impact has resulted in loss of tidal flats and brackish-water habitats.

Recommendations

- Ecological targets for estuaries need to be reformulated and tuned to the requirements of the relevant EC Directives in order to increase their operational value;
- The tidal freshwater reaches of estuaries should be integrated into the Leeuwarden definition of an estuary;
- Restoration of estuarine habitats (especially shallow areas and foreland) is necessary in all estuaries under consideration. Problems linked to the artificial increase of the tidal range have to be given special attention;
- Monitoring of long-term ecological changes in valuable parts of estuaries (to be specified!) is necessary;
- Consequences of further deepening, barriers and harbor extension should be evaluated carefully, taking into account the historical deterioration of the estuaries;
- For the Ems estuary, a long-term vision should be developed including the issue of a 2-channel or 1-channel system.

15.7 Offshore Area

The Offshore Area is positioned seaward of the Wadden Sea islands, extending to the 3 sea-mile limit, including the Conservation Area beyond this limit. This part of the Cooperation Area is in open connection with (a) the Wadden Sea and its estuaries, through a series of tidal inlets, and (b) the open North Sea. For the Offshore Area there are Targets with respect to natural geomorphology, favorable food availability for birds, and viability of stocks of marine mammals.

15.7.1 Geomorphology

The sediments of the seabed of the Offshore Area and of the channels and flats in the Tidal Area of the Wadden Sea form a coherent 'sand sharing' system. As a consequence of sea level rise, sand will be transported from the coast off the islands into the Wadden Sea.

Whereas coastal defense activities on the Wadden Sea islands have continued where necessary, no major changes in geomorphology or its dynamics can be reported since the 1999 QSR. One exception, the construction in 1995 of a 800 m long cross-shore dam at the northern tip of the island of Texel caused sand accretion at both sides of the dam extending the beach in seaward direction, and changes in the nearby ebb tidal delta.

Target

An increased natural morphology, including the outer deltas between the islands.

Target evaluation

- As far as available data shows, no major changes of natural morphology have taken place.

Conclusion

- Apart from coastal defense activities on the Wadden Sea islands (e.g., foreshore sand nourishments, cross-shore dam at Texel) no evidence has become available regarding any long-lasting negative development in natural dynamics of the geomorphology of the Offshore Area.

Recommendation

- Major coastal defense constructions should be accompanied by studies – both near field and far field – on their effects on seabed morphodynamics.

15.7.2 Biota

Regarding birds and marine mammals, more information has become available on the numbers

of individuals and proportion of their populations using the Offshore Area. One new insight is that common and grey seals from the Wadden Sea do use also the Offshore Area and open North Sea, covering great distances. The underlying cause has not yet been elucidated.

Harbour porpoises have become more numerous in the Offshore Area of The Netherlands and Niedersachsen, although the number of sightings is still low. In Schleswig-Holstein and Danish waters, the numbers remained more or less stable. There was an overall mean abundance of ca. 36,500 animals in the German Exclusive Economic Zone of the North Sea.

Repeated inventories have demonstrated the occurrence of important stocks of the bivalve *Spisula subtruncata* along the Dutch coast, and of *S. solida* along the coast of Schleswig-Holstein. These bivalves are a major food source for diving ducks such as common scoter and eider. Especially for the eider, these *Spisula* stocks are important for survival in the Wadden Sea when bivalve stocks are depleted either by severe winter conditions or by extensive shellfish fishery. In The Netherlands, there is a fishery for *Spisula*.

From the ICES North Sea Benthos Project 2000 it appears that the macrozoobenthos community in the Offshore Area is part of coastal communities along the Belgian-Dutch-German coast, characterized by low species numbers, but locally enhanced where complex substrate (sand, gravel, stones) is present, such as near Borkum Riff and in the outer Amrum Grounds.

Target

1. A favorable food availability for birds.
2. Viable stocks and a natural reproduction capacity of the common seal, grey seal and harbour porpoise.

Target evaluation

1. Stocks of the bivalve *Spisula* constitute a favorable food source for diving ducks, provided fishing pressure on these bivalve stocks is low;
2. (See section 15.9 for evaluation of Target 2.)

Conclusions

- The Offshore Area seems to play a more important role in the life cycle of the harbour seal, grey seal and harbour porpoise than reported in the 1999 QSR;
- Bivalve stocks in the Offshore Zone are important as a food resource for common scoter, eider and other diving ducks. For the eider,

Spisula stocks in the Offshore Area are an essential escape during adverse conditions in the Wadden Sea.

Recommendations

- Further research is needed to elucidate the specific role and importance of the Offshore Area in the life cycle of harbour porpoise, grey seal and common seal;
- A proper management of *Spisula* fishery needs to be developed to ensure compliance with the target 'favorable food availability for birds', especially for common scoter, common eider and velvet scoter.

15.8 Birds

Two major groups of birds have been considered, *viz.* breeding birds and migratory birds. For these birds, the Wadden Sea with its salt marshes, dunes, beaches and tidal flats constitutes a wetland of extreme high standard. It accommodates essential populations' requirements, such as moulting, wintering, roosting and staging during seasonal migrations as well as breeding. The availability of food and low level of disturbance are essential factors. For 43 species the Wadden Sea supports more than 1% of the flyway populations, being the criterion of the Ramsar Convention. Of these, 4 are breeding birds, 24 are breeding as well as migratory and 15 use the Wadden Sea only during their seasonal migrations. Of all migratory birds, 29 species occur with more than 10% of their flyway population.

For more than 30 birds species, the Wadden Sea area is important as breeding area. Breeding habitats are present in salt marshes, dunes, pastures and on beaches.

The trilateral targets regarding migratory and breeding birds relate to favorable food availability, natural flight distances, natural breeding success and undisturbed roosting and moulting areas.

15.8.1 Breeding birds

Among the 31 bird species monitored are 6 species with more than 25% of the NW European populations breeding in the Wadden Sea area. Two species are very rare after a long-term decline, *viz.* ruff and dunlin. For four rare species too, the Wadden Sea is situated on the edge of their European breeding range.

Over the period 1990-2001 and considering the entire Wadden Sea, ten species increased significantly, mainly due to expansion of their geographical breeding range. For common eider and arctic tern, this trend changed into a decreasing one in 1996 and 1998, respectively.

Breeding success

Significant declines in numbers occurred in nine species, although most recent counts showed a levelling off in three of these species. Only the great ringed plover and kentish plover, both breeding on beaches, showed an ongoing decline. More species have been declining in The Netherlands and Niedersachsen as compared to the other parts of the Wadden Sea, the underlying causes of which are only partly understood.

The ongoing decline in numbers of the great ringed plover and kentish plover is caused by increased recreational pressure on beaches and other breeding habitats. Meanwhile, protection measures taken at many breeding sites of the little tern have been successful, resulting in a trend towards recovery.

Food availability

The breeding populations of common eider (>75% in the Dutch Wadden Sea), oystercatchers and probably also herring gull have declined mainly in the Dutch Wadden Sea. This is considered an effect of intense shellfish fisheries notwithstanding the management measure of reserving certain amounts of cockle and blue mussel stocks for birds.

Predation pressure

In some species, a shift in breeding numbers from mainland coast to the islands was observed, caused by increasing predation pressure by mammalian predators, e.g. the red fox.

Among the species breeding in salt marshes (e.g., waders, passerines) various trends and fluctuations have been observed, however, without a clear relationship with changes in agricultural use or vegetation development of these areas. Too few studies attempting to provide explanations have been undertaken.

Target

Favorable conditions for [migrating and] breeding birds:

- A favorable food availability,
- [- Natural flight distances],
- A natural breeding success,
- [- Sufficiently large undisturbed roosting and moulting areas.]

Target evaluation

- The target 'A favorable food availability' has not been met, especially for bivalve eating species in the Dutch Wadden Sea due to shellfish fisheries;

- The target 'A natural breeding success' has still not been met for beach-breeding species due to recreational disturbance.

Conclusions

- For eider and oystercatcher, food conditions in the Dutch Wadden Sea have not been favorable due to shellfish fisheries, causing a decline of the breeding population;
- Measures aimed at protection of breeding sites of the little tern have proven successful;
- Numbers of breeding great ringed plover and kentish plover have continued to decline. Here protection measures have not been successful;
- Increasing predation pressure, e.g. by the red fox, has caused a shift of some breeding birds from mainland coast to the islands;
- Changes in breeding bird numbers in salt marsh habitats could not be linked to either management regime or vegetation development, mainly due to the absence of proper studies. Protection of species seriously at risk may be improved by compiling a list of such species for the Wadden Sea to assist the execution of EC Birds and Habitats Directives.

Recommendations

- Implementation with urgency of effective measures to protect beach-breeding birds such as great ringed plover and kentish plover;
- A more effective conservation of shellfish stocks in the Dutch Wadden Sea is necessary to ensure favorable food conditions for shellfish-eating birds. The new policy as of 1 January 2005 designed for reaching this goal needs to be monitored and evaluated after some years;
- Prevention of introduction to the islands of mammalian predators;
- Further studies into the underlying causes of changes in the abundance and occurrence of salt-marsh breeding birds, including studies on reproduction success;
- For more effective conservation a list of bird species seriously at risk in the Wadden Sea area should be drawn up.

15.8.2 Migratory birds

An analysis of trends of migratory waterbirds utilizing the Wadden Sea reveals that 22 out of 34 waterbird species experienced declines in 1992–2000, of which 15 are statistically significant. This

development is an alarming and new phenomenon since the 1999 QSR. Since declines of these species have not been observed elsewhere, the Wadden Sea may be the main bottleneck. For most of the declining species the Wadden Sea represents an indispensable stopover for 'fast refueling' during their long-distance migration to their breeding and wintering areas.

Food availability

Of the 22 species showing a decreasing trend, 19 were dependent on feeding on benthos, incl. bivalves, for 'fast refueling' during their migration to the breeding and wintering areas. This is an indication of non-favorable food availability, although other risk factors such as wintering in Africa and breeding in the (sub)arctic may play a role. For the bird species within this group and specializing in molluscs (e.g. eider, oystercatcher, knot and herring gull), food availability was impaired due to shellfish fishery. For herbivorous species (e.g., dark-bellied brent goose, Eurasian wigeon, barnacle goose) food availability seems not to be limited.

Roosting areas

High tide roosts are relatively well protected, with more than 80% of these roosts being located within Special Protection Areas. Despite this, disturbances occur due to outdoor recreation, hunting, civil air traffic and military training activities. Some species, such as dark-bellied brent goose, Eurasian golden plover, and Eurasian curlew, preferably use high tide roosts that are located at inland agricultural areas. These roosts are less protected, or not protected at all (e.g. in The Netherlands).

Moultng areas

For three species important moultng areas exist in the Wadden Sea and offshore zone. Practically the entire northwest European common shelduck population moults in the southern part of the Schleswig-Holstein Wadden Sea. The National Park Agency responsible has been successful in entering into effect voluntary agreements with different user groups aimed at avoidance of disturbance during the moultng season.

Moultng areas used by the common eider are more dispersed along the coast, as well as in the center of the German Bight, and situated preferably in areas with low disturbance.

For common scoter, moultng areas are in the offshore zone, decreasing in importance from north to south. A realistic estimate of the numbers moulting in the Wadden Sea area does not, however, exist. Moultng areas are chosen according to the presence of their favored food resource

(e.g., bivalves *Spisula* spp.) and low disturbance level. Common scoters are easily disturbed by ships and airplanes, and their food resources affected by shellfish fishery.

Flight distances

The knowledge of natural flight distances of bird species occurring in the Wadden Sea area is still poor. The common scoter is sensitive to disturbance, having a flight distance of up to 2,000 m from approaching ships. The successive steps in reducing hunting pressure in Denmark are considered to have had a positive effect on Eurasian curlew numbers in the Wadden Sea area. No information, however, has become available on any related decrease of flight distance in this bird species. For geese species, different flight distances have been reported from areas with and without hunting.

Target

Favorable conditions for migrating [and breeding] birds:

- A favorable food availability,
- Natural flight distances,
- [- A natural breeding success,]
- Sufficiently large undisturbed roosting and moultng areas.

Target evaluation

- For bird species feeding on benthos/bivalves the target 'favorable food conditions' has not been met; for herbivorous birds this target has been met;
- The target 'natural flight distances' cannot be evaluated due to absence of relevant data;
- The target 'sufficiently large undisturbed roosting and moultng areas' is still not satisfactorily met.

Conclusions

- Decreasing overall trends in migratory bird species indicate non-favorable conditions with respect to the availability of their food organisms bivalves and other benthos;
- Food availability seems no problem for herbivorous bird species;
- Protection of moultng shelduck has been improved through voluntary agreements with different user groups aimed at avoidance of disturbance during the moultng season;
- There are gaps in knowledge regarding specific habitat requirements and sensitivity to disturbance of moultng common scoter and

common eider, preventing an optimal protection of this species;

- Still little information is available on flight distances and their dependency on various types of disturbance. This hampers optimal measures for protection.

Recommendations

- Further research and monitoring is needed to elucidate the possible cause of the observed decreasing trends in migratory bird species, most of which are feeding on bivalves and other benthos;
- Continued attention for conservation of shellfish stocks to ensure favorable conditions for benthos-eating migratory birds;
- Measures to be taken to reduce the still existing conflicts between roosting birds and various sources of anthropogenic disturbance;
- Further research and monitoring effort is needed to fill the gaps in knowledge regarding moulting common scoter and common eider and their protection;
- Seek solutions for co-existence of geese and farmers through balanced management schemes, and further develop geese management on a flyway level;
- Further study of flight distances in relation to sources of disturbance.

15.9 Marine mammals

Regarding marine mammals two targets apply, one for the Offshore Area and one for the Tidal Area, which were agreed at the Leeuwarden Conference (1994). As in the 1999 QSR, for these mammals the combined target will be evaluated.

15.9.1 Harbour (= common) seal

After the PDV-epizootic in 1988, the harbour seal population in the Wadden Sea recovered prosperously and increased to approx. 21,000 in 2002, at an almost exponential rate. In 2002, a second PDV-epizootic struck the population, reducing numbers by around 50%; mortality was higher in adult males than in adult females. As a result, a relatively high proportion of pups was observed in 2003, providing a quick start of recovery of the population.

There has been an improvement of the health condition of harbour seals in general.

Application of satellite transmitters has shown that harbour seals from the Wadden Sea use the North Sea to a much greater extent than realized before. The reason for this is yet not clear, but may be related to the population's exponential

growth and/or to decreased availability of food in the Wadden Sea and adjacent coastal waters.

Target

Viable stocks and a natural reproduction capacity of the common seal [grey seal and harbour porpoise].

Target evaluation

- The population of harbour seals in the Wadden Sea can be considered viable with a satisfactorily reproduction capacity.

Conclusions

- The harbour seal population in the Wadden Sea increased to approx. 21,000 in 2002 until a second PDV-epizootic halved the population. In 2003 recovery started with a relatively high production of pups. The population seems to be viable with a satisfactorily reproduction capacity;
- Seals from the Wadden Sea use the North Sea to a much greater extent than realized before. The reason for this is not clearly known.

Recommendations

- For optimal conservation of the harbour seal population, the recommendations of the Seal Management Plan 2002-2006 should be implemented;
- Research on feeding ecology should be undertaken to further quantify and elucidate the reasons behind the widespread occurrence in the North Sea of harbour seals from the Wadden Sea;
- Further studies of the impact of expanding offshore activities on foraging and migratory behavior of harbour seals.

15.9.2 Grey seal

Since the 1999 QSR, grey seal numbers in the Wadden Sea have increased. In The Netherlands, numbers have more than doubled; in Schleswig-Holstein an increase was also observed. Although pup production has increased, the increase rate of the population is for a significant proportion due to influx of animals from the east coast of the United Kingdom. Recently, signs of expansion to other parts of the Wadden Sea (Borkum Riff, Norderney) and inner German Bight (Helgoland) were observed, yet without any significant breeding. Conservation of grey seals in the Wadden Sea must involve effective protection of colony sites, particularly during the breeding and moulting sea-

sons. Such protection is currently implemented in Schleswig-Holstein, but not in The Netherlands, where major colonies fall outside the Conservation Area. Furthermore, there is lack of knowledge of basic biology of the species in the Wadden Sea area.

Target

Viable stocks and a natural reproduction capacity of the [common seal,] grey seal [and harbour porpoise].

Target evaluation

- The target regarding grey seals cannot be evaluated due to insufficient data and knowledge.

Conclusions

- The numbers of grey seal in the colonies in the Dutch and Schleswig-Holstein part of the Wadden Sea increased, to a large extent being caused by influx from elsewhere. In 2003, signs of population expansion to other areas were observed;
- Conservation of grey seals in the Dutch Wadden Sea does not involve effective protection of colony sites, particularly during the breeding and moulting seasons;
- There is insufficient data and knowledge to judge whether the population in the Wadden Sea is viable, or has a natural reproduction capacity.

Recommendations

- For optimal conservation of the grey seal population, the recommendations of the Seal Management Plan 2002–2006 should be implemented;
- Studies to be initiated of basic population biology of grey seal and their habitat use to provide essential information to formulate appropriate management;
- Improved protection of grey seal colonies in the Wadden Sea and the Offshore Area, including also newly developing colonies;
- Adaptation of spatial coverage of monitoring of grey seals in order to design adequate management.

15.9.3 Harbour porpoise

Within the Wadden Sea itself and the adjacent Offshore Area, dedicated trilateral surveys do not exist. In Danish waters, dedicated surveys started in 2000 in connection with the offshore wind farm on Horns Reef. In the German sector of the North Sea, aerial surveys started in 2002 as part of offshore wind farm studies. In 2002 and 2003 in highest densities of harbour porpoise within the German Bight were observed off Schleswig-Holstein. Offshore developments, such as wind farms, and North Sea fishery form a potential threat to the harbour porpoise population(s). The impacts of these human activities are still insufficiently known.

Target

Viable stocks and a natural reproduction capacity of the [common seal, grey seal and] harbour porpoise].

Target evaluation

- The target regarding harbour porpoise cannot be evaluated due to insufficient information.

Conclusions

- No statement regarding viability of stock or natural reproduction capacity can be made, due to insufficient information;
- The Offshore Area and adjacent North Sea, especially off Schleswig-Holstein, is important for harbour porpoise. Dedicated trilateral (TMAP) surveys, however, do not exist.

Recommendations

- Organization of cooperative effort for better surveying the occurrence of harbour porpoise inside and outside the Cooperation Area;
- The national regulations of the Whale Sanctuary off Sylt and Amrum should be embedded in EU law in order to make protection more effective;
- Further studies of the impact of fisheries (e.g. by-catch) and offshore wind farms on harbour porpoise.

15.10 Summary of Target evaluation

In the table below an overview is presented of the evaluation of the Targets of the Wadden Sea Plan. To assist a quick overview, colored symbols have been used. These symbols should be interpreted in combination with the text of the evaluation. The meaning of the symbols is as follows:

- ▼ target not reached; development negative,
- ▲ target not yet reached; positive development,
- ▲ green target reached, positive development,
- ▼ green target reached, negative development
- ? no target evaluation possible.

Issue	Target	Evaluation
Nutrients & Eutrophication	A Wadden Sea which can be regarded as a eutrophication non-problem area.	▲ Though phosphate concentrations have decreased, the entire Wadden Sea still has to be considered a eutrophication problem area, meaning that the target has not yet been met.
Hazardous substances	Background concentrations of natural micropollutants in water, sediment and indicator species.	▲ For metals in sediment the target has not yet been reached in all subareas of the Wadden Sea. For four metals concentrations in blue mussel do not yet meet target levels. Mercury in bird eggs does not yet meet target levels. Regarding the OSPAR ecotoxicological assessment criteria, concentrations in the Wadden Sea of mercury, copper, cadmium and PAHs do not pose a risk to the ecosystem, but zinc and lead still do. For PAHs in sediment, no natural background level has been documented. Concentrations are lower than in the Skagerak, and higher than in Barents Sea sediments.
	Concentrations of man-made substances as resulting from zero discharges.	▲▼ Although for a number of xenobiotic compounds discharges to and concentrations in the Wadden Sea have decreased, the target has not yet been reached. For some substances, e.g. TPT and Lindane, a significant deviation from the target is apparent. For PCBs, Lindane and TBT, the OSPAR ecological assessment criteria are exceeded in various Wadden Sea subareas. Of many newly developed xenobiotics, including hormone disruptors, concentrations have been found in the Wadden Sea, which is a deviation from the target.
	OSPAR EcoQO: The proportion of oiled common guillemots among those found dead or dying on beaches should be 10% or less.	▲ For the common guillemot, the OSPAR Ecological Quality Objective (EcoQO) of 10% oil rate has not been met.
Salt marshes	An increased area of natural salt marshes.	? In most areas of the Wadden Sea, an increase in area of natural and semi-natural salt marshes could be observed. An evaluation, of the target in quantitative terms is, however, not possible for the entire area because of insufficiently detailed older data.
	An increased natural morphology and dynamics, including natural drainage patterns, of artificial salt marshes, under the condition that the present surface is not reduced.	▲? Artificial draining in salt marshes has been reduced. The remaining ditch systems, however, have not yet developed into natural-like creek systems.

Issue	Target	Evaluation
Salt marshes (cont.)	An improved natural vegetation structure, including the pioneer zone, of artificial salt marshes.	▲▼ A precise evaluation of the target cannot be given because long-term data is only available for some regions and the developed common typology could not be applied to older data. Significant reductions of livestock grazing intensity in The Netherlands and Germany contributed to a more natural vegetation structure of artificial mainland salt marshes. In Denmark, the proportion of intensively grazed salt marshes did not change considerably.
Tidal area – hydrology/geomorphology and macrozoobenthos	A natural dynamic situation in the Tidal Area. An increased area of geomorphologically and biologically undisturbed tidal flats and subtidal areas.	▲ The Tidal Area of the Wadden Sea is still characterized by a high degree of natural dynamics. There is no significant increase of constructions for coastal defense. ▲ Deviations from the target are existing coastal defense structures and deepening of channels for shipping. ?▼ The target cannot be evaluated due to absence of proper information. The observed decline in bivalve recruitment and shift in their centers of distribution indicates a loss of previously biologically undisturbed tidal flats, in other words: a deviation from the target.
Tidal area – biogenic structures	An increased area of, and a more natural distribution and development of natural mussel beds, <i>Sabellaria</i> reefs and <i>Zostera</i> fields.	▼ No increased area of <i>Sabellaria</i> reefs has been reported. ▲ The target of increased area of <i>Zostera</i> fields has not yet been met in all sub-areas of the Wadden Sea. ▲▲ The target of an increased area of natural mussel beds in the intertidal area was reached in the mid and eastern Dutch Wadden Sea. In the Danish and western Dutch Wadden Sea, no development according to the target occurred. In Niedersachsen, the actual area of mussel beds is the level present in the late 1980s, and in Schleswig-Holstein still below the level present in the early 1990s. ▲ In areas where there was no fishing, a more natural distribution and development of intertidal mussel beds occurred. ? With regard to the subtidal mussel beds, no evaluation of the target is possible yet.
Tidal area – introduced species	- no target -	- not applicable -
Tidal area – fish and shrimps	- no specific target - An increased area of geomorphologically and biologically undisturbed tidal flats and subtidal areas. A favorable food availability [for migrating and breeding birds].	? The target of undisturbed tidal flats and subtidal areas for fish and shrimps cannot be evaluated. The possibility of the observed shift in juvenile flatfish being related to a decreased area of undisturbed tidal flats and subtidal areas needs to be investigated. ▲ There is currently no evidence of food shortage among fish and shrimp eating birds.
Beaches and Dunes	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.	?▲ The target of increased natural dynamics of beaches and dunes cannot be fully evaluated due to absence of criteria and of comparable relevant data; natural dynamics have increased where coastal defense activities were stopped; remnant coastal defense structures still remaining restrict increased dynamics. ▲ A complete natural vegetation succession is not present because about two-thirds of the dune areas consists of mid-successional dune type and important other types are not present or show further decline.

Issue	Target	Evaluation
Estuaries	Valuable parts of estuaries will be protected and river-banks will remain and, as far as possible, be restored to their natural state.	▼ According to the Water Framework Directive Reports 2005, most estuaries in the Wadden Sea Cooperation Area fail to meet the target.
Offshore Zone	An increased natural morphology, including the outer deltas between the islands.	▲ As far as available data shows, no major changes of natural morphology have taken place.
	A favorable food availability for birds.	▲(▼) Stocks of the bivalve <i>Spisula</i> constitute a favorable food source for diving ducks, provided fishing pressure on these bivalve stocks is low.
	Viable stocks and a natural reproduction capacity of the common seal, grey seal and harbour porpoise.	- see under 'Marine mammals' -
Breeding birds	Favorable conditions for [migrating and] breeding birds: - A favorable food availability, - A natural breeding success.	▼ The target 'A favorable food availability' has not been met, especially for bivalve eating species in the Dutch Wadden Sea due to shellfish fisheries. ▼ The target 'A natural breeding success' has still not been met for beach-breeding species due to recreational disturbance.
Migratory birds	Favorable conditions for migrating and breeding birds: - A favorable food availability, - Natural flight distances, - Sufficiently large undisturbed roosting and moulting areas.	▲▼ For bird species feeding on benthos/bivalves the target 'favorable food conditions' has not been met; for herbivorous birds this target has been met. ? The target 'natural flight distances' cannot be evaluated due to absence of relevant data. ▲ The target 'sufficiently large undisturbed roosting and moulting areas' has still not satisfactorily been met.
Marine mammals	Viable stocks and a natural reproduction capacity of the common seal, grey seal and harbour porpoise.	▲ The population of harbour seals in the Wadden Sea can be considered viable with a satisfactorily reproduction capacity. ? The target regarding grey seal and harbour porpoise cannot be evaluated due to insufficient data and knowledge.

15.11 Summary of recommendations

Issue	Policy & Management	Monitoring & Research
Nutrients & Eutrophication	<ul style="list-style-type: none"> In order to meet the target, continued effort is necessary to effectively implement current policies to reduce nutrient inputs; special effort is necessary with regard to nitrogen compounds. 	<ul style="list-style-type: none"> The temporal and spatial resolution of monitoring should be adapted to better cover the algal growth season and the whole annual cycle. Development of a harmonized approach for determining water residence time in different parts of the Wadden Sea to enable proper assessment of observed nutrient concentrations. Research should be done with priority into 1) the causes of the observed differences in eutrophication status between different parts of the Wadden Sea, and 2) the role of suspension feeders, including the Pacific oyster and the American jack-knife clam in the chlorophyll dynamics when using chlorophyll as indicator of eutrophication. Further research is necessary to assess how fundamental processes, e.g. nutrient regeneration from organic matter in the sediment, oxygen dynamics and food-chain effects respond to decreasing nutrient input.
Hazardous substances	<ul style="list-style-type: none"> Continued attention on reduction of metal discharges through rivers debouching into the Wadden Sea. Nickel, being a high priority compound both in OSPAR and WFD, to be included in the TMAP and data units. Inclusion in TMAP of priority substances among the newly developed xenobiotics and hormone disruptors in connection with the requirements of the Water Framework Directive. Trilateral application of biological effects assessment techniques (e.g., bioassays, EDA, TIE) as a management and monitoring tool. Continuation and further implementation of policies and measures to prevent oil pollution, including education programs for seafarers. Analysis of oil residues on beaches and oiled birds washed ashore to be used to monitor the effectiveness of pollution control measures aimed at reduction of oil pollution from different sources. 	<ul style="list-style-type: none"> Continued effort regarding harmonization of methods of analysis and of standardization, both being necessary to make reliable comparisons at a geographical scale. Investigate the reason for anomalous metal concentrations in sediment found at two locations in subareas SH3 and DK2. Extra attention to be paid at some recently and locally increased contaminant concentrations and the sources of triphenyltin. Ecotoxicological research into the effects of organotin accumulation in common eider and harbour seal. Continued and well coordinated trilateral monitoring of beached birds is required to be able to assess the effect of the PSSA designation, and of North Sea wide oil pollution control policy.
Salt marshes	<ul style="list-style-type: none"> Further development of naturally growing salt marshes is best helped by leaving geomorphology of neighboring mudflats undisturbed. Further increase of area of (semi) natural salt marshes can be achieved by breaching protecting summer dikes or sand dikes. 	<ul style="list-style-type: none"> For vegetation mapping of de-embanked polders and other study sites, a frequency should be chosen tuned to the velocity of the salt-marsh development process. Further study and experiments into effective ways of facilitating the development of natural-like drainage creeks.

Issue	Policy & Management	Monitoring & Research
Salt marshes (cont.)	<ul style="list-style-type: none"> Cessation of artificial drainage in all salt marshes without any agricultural use, taking care of prevention of waterlogging of dike footings. To prepare a Wadden Sea wide assessment of salt-marsh vegetation development, based on the now available common vegetation typology, which also can be used for the requirements of the Habitats Directive. 	<ul style="list-style-type: none"> Study of the possible interrelationship between ageing towards climax vegetation, rate of sedimentation and cessation of grazing. Continuation of long-term study sites and incorporation of these sites into the International Long-Term Ecological Research sites (ILTER).
Tidal area – hydrology/geomorphology		<ul style="list-style-type: none"> For a better assessment of the targets, parameters should be developed within the TMAP to properly monitor changes in hydro-morphological dynamics and in geomorphologically and biologically undisturbed tidal flats and subtidal areas. A study should be undertaken into the effect of increased deepening for shipping on estuarine geomorphology, especially regarding changes in the amount and nature of tidal flats and subtidal areas. The signalized loss of high mud flats essential for bivalve settlement should be given more attention, through either monitoring or directed research.
Tidal area – macrozoobenthos	<ul style="list-style-type: none"> - see under blue mussel beds - 	<ul style="list-style-type: none"> Elucidation of the status of isolated populations of benthic invertebrates in estuarine and brackish habitats, and of the underlying cause of the long-term increase in polychaetous worms, and of shifting centers of bivalve recruitment.
Tidal area – biogenic structures: <i>Sabellaria</i> reefs	<ul style="list-style-type: none"> The <i>Sabellaria</i> reefs should be designated as Special Area of Conservation, where especially seabed disturbing activities (sand extraction, dredging, bottom trawling) are not allowed. Human interventions changing the water current conditions should be considered carefully as they may affect <i>Sabellaria</i> reefs. 	<ul style="list-style-type: none"> A program should be launched under the TMAP to properly monitor existing <i>Sabellaria</i> reefs, and to explore the occurrence of reef constructions in potential reef areas in the Wadden Sea Cooperation Area. New reefs found should be considered for monitoring.
Zostera fields	<ul style="list-style-type: none"> Given the diminished and, in some areas, still endangered state of seagrasses, negative effects of shellfish fishery and land reclamation works at existing and potential sites of seagrass beds should be avoided. Further reductions in nutrient loads would strengthen the vitality of seagrass when growing at average salinities. Reintroductions of intertidal sea grass in the southern Wadden Sea should focus on optimal sites and employ founding populations of considerable size to achieve self maintenance. 	<ul style="list-style-type: none"> Restoring of ebb-slusices with continuous freshwater runoffs to explore their positive effects on local seagrass development. Further study of the effectiveness of re-introduction programs of intertidal seagrass, as well as a study of the feasibility of re-introduction of the large morph of <i>Zostera marina</i>. Improved harmonization of monitoring of and research into seagrass in the Wadden Sea.

Issue	Policy & Management	Monitoring & Research
Blue mussel beds	<ul style="list-style-type: none"> Because of their high biodiversity and ecological importance, a protection regime should be designed for subtidal mussel beds; subtidal and intertidal beds should also be considered as a biological quality element in the relevant EC Directives. The management measure of protecting stable mussel beds or sites (intertidal as well as subtidal) is still valid. 	<ul style="list-style-type: none"> Investigation into the cause of the failing recruitment of littoral mussels and mussel beds in Niedersachsen, Schleswig-Holstein and Denmark. The proliferation of the Pacific oyster should be monitored, and its competitive mechanism leading to the taking over of mussel beds investigated, with a view of developing options for management. Extension, if possible, of the habitat model developed as a management tool for intertidal mussel beds in the Dutch Wadden Sea to the German and Danish Wadden Sea as well.
Tidal area – introduced species	<ul style="list-style-type: none"> Consider appropriate precautionary measures to prevent further introduction of species that may constitute a risk to the Wadden Sea ecosystem. 	<ul style="list-style-type: none"> The TMAP should be alert to discover new immigrant species, and may need to be adapted to provide data for impact assessment of introduced species; Study of the ecological function of the newly developing reefs of Pacific oysters.
Tidal area – fish and shrimps	<ul style="list-style-type: none"> The formulation of trilateral targets regarding fish, tuned to the requirements of the relevant Directives, will structure and focus research and monitoring of this important faunal group in the Wadden Sea. For threatened diadromous fish species further conservation effort is required, e.g. sluice and dike passage facilities and upstream habitat restoration. 	<ul style="list-style-type: none"> The existing demersal fish survey programs should be trilaterally coordinated and harmonized to provide valuable information on the quality of the Wadden Sea as a habitat for demersal fish. Development of trilaterally coordinated pelagic fish monitoring program, especially aimed at obtaining data about fish species depending on upstream water quality and breeding habitat. Studies should be undertaken to improve the ecological knowledge of non-commercial species, to investigate the functional relationship between fish species and specific habitats such as mussel beds and other hard substrate, and to obtain insight in the factors underlying the shift in distribution in juvenile flatfish.
Beaches and Dunes	<ul style="list-style-type: none"> The trilateral targets with respect to beaches need to be reconsidered and redefined against the background of (1) sea level rise and concomitant intensification of coastal defense, and (2) increased recreational pressure on the coastline. Existing differences in dune management regimes make a case for exchange of information on this issue among managers involved. The use of the newly developed TMAP classification for dunes for trilateral assessment of dunes development, and concurrent data collection concerning atmospheric deposition, coastal protection measures and water management. 	<ul style="list-style-type: none"> A better exchange of information about how coastal protection measures and remnant sand dikes influence pioneer stages and possibilities for restoring natural dynamics. An inventory of the differences in water extraction management and of their ecological consequences. More fundamental studies of the speed and direction of natural succession under different conditions, with the aim of contributing to future policy and management questions concerning the Wadden Sea dunes.

Issue	Policy & Management	Monitoring & Research
Estuaries	<ul style="list-style-type: none"> Ecological targets for estuaries need to be reformulated and tuned to the requirements of the relevant EC Directives in order to increase their operational value. The tidal freshwater reaches should be integrated into the Leeuwarden definition of an estuary. Restoration of estuarine habitats (especially shallow areas and foreland) is necessary in all estuaries under consideration. Problems linked to the artificial increase of the tidal range have to be given special attention. For the Ems estuary, a long-term vision should be developed, including the issue of a 2-channel or 1-channel system. 	<ul style="list-style-type: none"> Monitoring of long-term ecological changes in valuable parts (to be specified) of estuaries is necessary. Consequences of further deepening, barriers and harbor extension should be evaluated carefully, taking into account the historical deterioration of the estuaries.
Offshore Area	<ul style="list-style-type: none"> Major coastal defense constructions should be accompanied by studies – both near field and far field – on their effects on seabed morphodynamics. A proper management of <i>Spisula</i> fishery needs to be developed to ensure compliance with the target 'favorable food availability for birds', especially for common scoter, common eider and velvet scoter. 	<ul style="list-style-type: none"> Further research is needed to elucidate the specific role and importance of the Offshore Area in the life cycle of harbour porpoise, grey and harbour seal.
Breeding birds	<ul style="list-style-type: none"> Implementation with urgency of effective measures to protect beach-breeding birds such as great ringed plover and Kentish plover. Prevention of introduction to the islands of mammalian predators. For more effective conservation a list of bird species seriously at risk in the Wadden Sea area should be drawn up. 	<ul style="list-style-type: none"> Further studies into the underlying causes of changes in abundance and occurrence of salt marsh breeding birds, including studies of reproduction success. A more effective conservation of shellfish stocks in the Dutch Wadden Sea is necessary to ensure favorable food conditions for shellfish-eating birds. The new policy as of 1 January 2005 designed for reaching this goal needs to be monitored and evaluated after some years.
Migratory birds	<ul style="list-style-type: none"> Continued attention for conservation of shellfish stocks to ensure favorable conditions for benthos-eating migratory birds; Measures to be taken to reduce the still existing conflicts between roosting birds and various sources of anthropogenic disturbance; Seek solutions for co-existence of geese and farmers through balanced management schemes, and further develop goose management on a flyway level. 	<ul style="list-style-type: none"> Further research and monitoring is needed to elucidate the possible cause of the observed decreasing trends in migratory bird species, most of which are feeding on bivalves and other benthos; Further research and monitoring effort is needed to fill the gaps in knowledge regarding moulting common scoter and common eider and their protection; Further study of flight distances in relation to sources of disturbance.
Marine mammals	<ul style="list-style-type: none"> For optimal conservation of the populations of harbour seal and grey seal, the recommendations of the Seal Management Plan 2002-2006 should be implemented. 	<ul style="list-style-type: none"> Research on feeding ecology should be undertaken to further quantify and elucidate the reasons behind the widespread occurrence in the North Sea of harbour seals from the Wadden Sea. Further studies of the impact of expanding offshore activities on foraging and migratory behavior of harbour seals.

Issue	Policy & Management	Monitoring & Research
Marine mammals (cont.)	<ul style="list-style-type: none"> • Improved protection of grey seal colonies in the Wadden Sea and the Offshore Area, including also newly developing colonies. • The national regulations of the Whale Sanctuary off Sylt and Amrum should be embedded in EU fishery legislation in order to make protection more effective. 	<ul style="list-style-type: none"> • Studies to be initiated of basic population biology of grey seals and their habitat use to provide essential information to formulate appropriate management. • Adaptation of spatial coverage of monitoring of grey seals in order to design adequate management. • Organization of cooperative effort for better surveying the occurrence of harbour porpoise inside and outside the Co-operation Area. • Further studies of the impact of fisheries (e.g. by-catch) and offshore wind farms on harbour porpoise.

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List of Acronyms

AEWA	Agreement on the Conservation of African-Eurasian Waterbirds
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas
BD	Council Directive 79/409/EEC on the Conservation of Wild Birds (Birds Directive)
CBD	Convention on Biological Diversity
CPSL	Trilateral Working Group on Coastal Protection and Sea Level Rise
CMS	Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
CWSS	Common Wadden Sea Secretariat
EcoQO	Ecological Quality Objectives
ED	Esbjerg Declaration
EEA	European Environmental Agency
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
HD	Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive)
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Organization of the United Nations
IPCC	Intergovernmental Panel on Climate Change
IRWC	Inter-regional Wadden Sea Cooperation
JMBB	Joint Monitoring of Breeding Birds
JMMB	Joint Monitoring of Migratory Birds
MAB	Man and Biosphere
MARPOL	International Convention for the Prevention of Pollution from Ships
NGO	Non-Governmental Organization
NSC	North Sea Conference
OSPAR	Oslo and Paris Convention
PDV	Phocine Disease Virus
PSSA	Particularly Sensitive Sea Area
QSR	Quality Status Report
SAC	Special Area of Conservation
SCI	Site of Community Importance
SD	Stade Declaration
SMP	Seal Management Plan
SPA	Special Protection Area
TMAP / G	Trilateral Monitoring and Assessment Program / Group
TSEG	Trilateral Seal Expert Group
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
WFD	Council Directive 2000/60/EC on Establishing a Framework for Community Action in the Field of Water Policy (Water Framework Directive)
WSF	Wadden Sea Forum
WSP	Trilateral Wadden Sea Plan
WWF	World Wide Fund for Nature

