Wadden Sea
Quality Status Report
2004

Colophon

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Editors
Karel Essink, Rijksinstituut voor Kust en Zee (RIKZ), Haren;
Carsten Dettmann, Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU), Bonn;
Hubert Farke, Nationalparkverwaltung Niedersächsisches Wattenmeer (NLPV), Wilhelmshaven;
Karsten Laursen, Danmarks Miljøundersøgelser (DMU), Rønde;
Gerold Lüerßen, Common Wadden Sea Secretariat (CWSS), Wilhelmshaven;
Harald Marencic, Common Wadden Sea Secretariat (CWSS), Wilhelmshaven;
Wim Wiersinga, Expertise Center, Ministerie van Landbouw, Natuur en Voedselkwaliteit (EC-LNV), Ede.

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WADDEN SEA ECOSYSTEM No. 19

Wadden Sea Quality Status Report 2004

Karel Essink
Carsten Dettmann
Hubert Farke
Karsten Laursen
Gerold Lüerßen
Harald Marencic
Wim Wiersinga

2005
Trilateral Monitoring and Assessment Group
Common Wadden Sea Secretariat

Cees Veerman
Minister of Agriculture, Nature and Food Quality, Chair of the Trilateral Wadden Sea Cooperation

Knowledge is the basis of good Wadden Sea policy

In order to make good decisions, politicians need a sound base of knowledge. This is especially true when the future of a unique nature area such as the Wadden Sea is at stake. In a region like this, governed by three countries and with many different interests jostling for attention, it is not enough to simply be aware of the state of the environment and nature. We must also understand the consequences of our political decisions. The Quality Status Report (QSR) provides us with this information: it describes and evaluates recent developments, including the effects of the policies implemented by the three Wadden Sea countries.

The QSR is an invaluable source of information, not only for policy-makers, but for the many interest groups in the Wadden Sea region as well. The QSR supplies objective data that helps interest groups form their opinion, contributes to their debates and enriches their dialogue with us policy-makers. Debate and dialogue are essential preconditions of sensible, broadly-supported policy.

I am pleased to note that, for the first time, the writers of the QSR have tapped into the operational data exchange system of the Trilateral Monitoring and Assessment Program (TMAP). This system plays a vital role in the Trilateral Wadden Sea Cooperation. It forms the basis of the periodic assessments of the Wadden Sea ecosystem, as well as the evaluation of the ecological targets set in the Wadden Sea Plan.

This QSR gives us reason to be optimistic on many counts, but there is also some cause for concern. It is good to see that many of our targets have been achieved: the salt marshes are developing well, there is enough food for fish-eating and plant-eating birds, and the seal population is healthy and viable, even after the 2002 distemper epidemic. Policy to reduce the input of nutrients is also having the desired effect: the rivers flowing into the Wadden Sea are less polluted with nutrients and other contaminants, causing a gradual turnaround in the eutrophication of the Wadden Sea.

Causes for concern are reports of an increase in hazardous substances in the Wadden Sea, declining numbers of migratory birds and poor reproduction amongst beach-nesting birds.

Next to this inventory of developments, the QSR also identifies subjects that warrant further study and forecasts possible future developments. For the future of the Wadden Sea, the QSR underscores yet again the importance of international policy outside the trilateral cooperation. For example, policy on international shipping, the introduction of exotic species, climate change and possible changes in the composition of the sediment.

All in all, the report gives us plenty of food for thought. It will also make a vital contribution to the 10th Trilateral Governmental Wadden Sea Conference, on Schiermonnikoog, to be hosted by The Netherlands.

As Minister of Agriculture, Nature and Food Quality in The Netherlands and chair of the Trilateral Wadden Sea Cooperation, I would like to compliment all those who contributed to the QSR. They have done an excellent job. I thank those who kept the TMAP running and the QSR Management Team, the Common Wadden Sea Secretariat (CWSS) and the many scientists and volunteers for contributing their expertise and enthusiasm. Thanks to this joint effort, our beautiful Wadden Sea region can count on sound policy which looks to the future.

Cees Veerman
Minister of Agriculture, Nature and Food Quality
Chair of the Trilateral Wadden Sea Cooperation

Editorial Foreword

In the Trilateral Wadden Sea Cooperation, a central role is played by the Trilateral Monitoring and Assessment Program (TMAP) which provides the basis for a periodic assessment of the status of the Wadden Sea ecosystem, and for an evaluation of the implementation status of the ecological targets formulated in the Wadden Sea Plan. A process to optimize the TMAP with regard to the EC Water Framework, Birds and Habitats Directives is presently ongoing.

In 2003, the Trilateral Working Group (TWG) commissioned the Trilateral Monitoring and Assessment Group (TMAG) to organize the drafting of a new Quality Status Report (QSR). This new QSR was intended to be an update of the 1999 QSR rather than a full new QSR. As a consequence, the structure of the 1999 QSR was largely kept. Only in a few cases information is presented in a new chapter.

For the compilation of this QSR Update 2004, for the first time a common TMAP data exchange system was used which has became operational during 2004. It provides access to harmonized monitoring data from the four TMAP data units in the Netherlands, Niedersachsen, Schleswig-Holstein/Hamburg and Denmark.

The QSR Update 2004 was prepared under the responsibility of the TMAG and organized by the QSR Management Team, an ad-hoc working group under the TMAG, and the Common Wadden Sea Secretariat (CWSS). The following persons participated in the QSR Management Team:
Dr. Karel Essink, National Institute for Coastal and Marine Management (RIKZ), Haren (chairman);
Mr. Carsten Dettmann, Federal Ministry for the Environment, Nature Protection and Nuclear Safety (BMU), Bonn (2004-2005);
Dr. Hubert Farke, Nationalparkverwaltung Niedersächsisches Wattenmeer, Wilhelmshaven;
Dr. Karsten Laursen, National Environmental Research Institute (NERI), Rønde
Mr. Rasso Leinfelder, Federal Ministry for the Environment, Nature Protection and Nuclear Safety (BMU), Bonn (2003);
Mr. Gerold Lüerßen, Common Wadden Sea Secretariat (CWSS), Wilhelmshaven;
Dr. Harald Marencic, Common Wadden Sea Secretariat (CWSS), Wilhelmshaven;
Mr. Wim Wiersinga, Expertise Center, Ministry of Agriculture, Nature and Food Quality (EC-LNV), Ede.

This report consists of 13 chapters containing basic information on human activities in the Wadden Sea and on developments in physico-chemical and ecological conditions. The material presented was made available through the four TMAP data units and through involvement of experts from government institutes, universities, consultants and volunteers. Factual information more recent than December 1st, 2004 is not included.

In chapter 14 a synoptic overview is presented viewing at the Wadden Sea ecosystem. Finally, in chapter 15 an evaluation is given of the Targets of the Trilateral Wadden Sea Plan (1997).

These chapters are intended to provide a basis for discussions among experts, managers and policy makers in the preparation of the 10th Trilateral Wadden Sea Conference (Schiermonnikoog, November 3, 2005), where the focus and tasks for the next period of Trilateral Wadden Sea Cooperation will be defined.

The Editors

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1. Introduction

Harald Marencic
Karel Essink
Adolf Kellermann
Kai Eskildsen

The Wadden Sea (Landsat TM satellite images of the period 2000–2002, Source: CWSS, Brockmann Consult).

1.1 General Description

Harald Marencic
Karel Essink

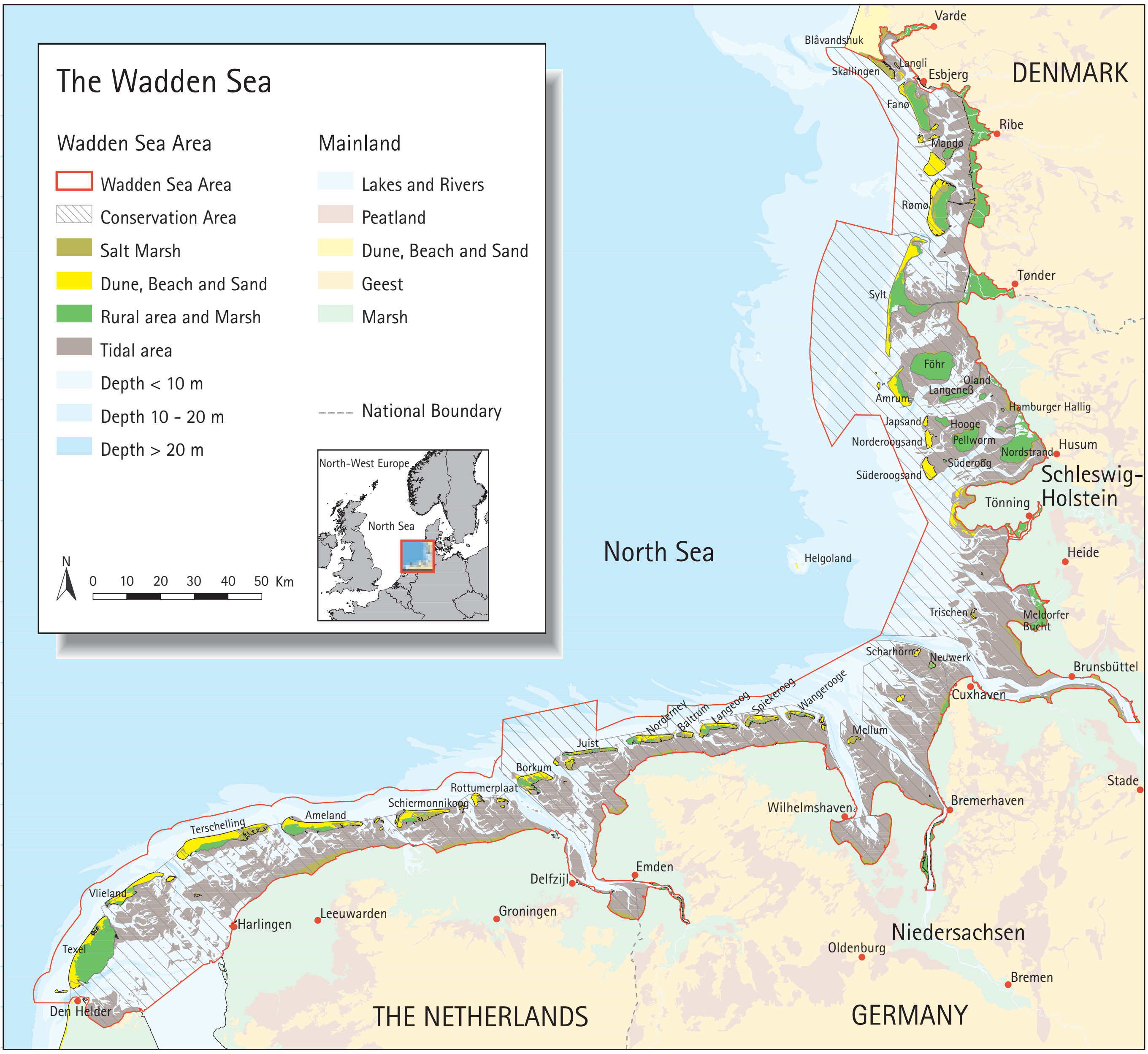
The Wadden Sea is a coastal sea stretching over 450 km along the North Sea coast of the Netherlands, Germany and Denmark and is one of the largest wetlands on a global scale.

A network of tidal channels, sandbars, mudflats, salt marshes and islands creates a transition zone between land and sea characterized by daily changing flood and ebb tides and high dynamics in salinity, light, oxygen and temperature. This has resulted in a complex system which provides a unique habitat for a rich flora and fauna (Figure 1.1).

The great productivity and size of the Wadden Sea provide a foundation for the reproduction of North Sea fish stocks and for its function as a turntable of bird migration. The ecological importance of the Wadden Sea thus extends from the Arctic to South-Africa.

The Wadden Sea is an open system and there are many interactions with the adjacent North Sea. The quality of water, sediment and marine habitats is, to an important degree, influenced by the North Sea and activities in the catchment area of the debouching rivers (Figure 1.2).

Figure 1.1:
The Wadden Sea.



The OSPAR Quality Status Report for the North Sea gives a comprehensive overview about geography, hydrography and climate of the North Sea and numerous influences from land-based as well as sea-based human activities (OSPAR Commission, 2000).

The Wadden Sea region (Figure 1.3) is also an area where people live, work and recreate. About 3.7 million people live along the Wadden Sea coast, of which about 75,000 live inside the Wadden Sea Area. The Trilateral Wadden Sea Plan (1997) acknowledges this by stating that economic and social values should also be maintained and enhanced.

With the establishment of a Wadden Sea Forum as an independent stakeholeder forum, the inhabitants of the Wadden Sea region have been given an opportunity to get actively involved in the activities of the Trilateral Wadden Sea Cooperation. The final report of the Forum presents common views on the future and of a sustainable development perspective for the region (Wadden Sea Forum, 2005).

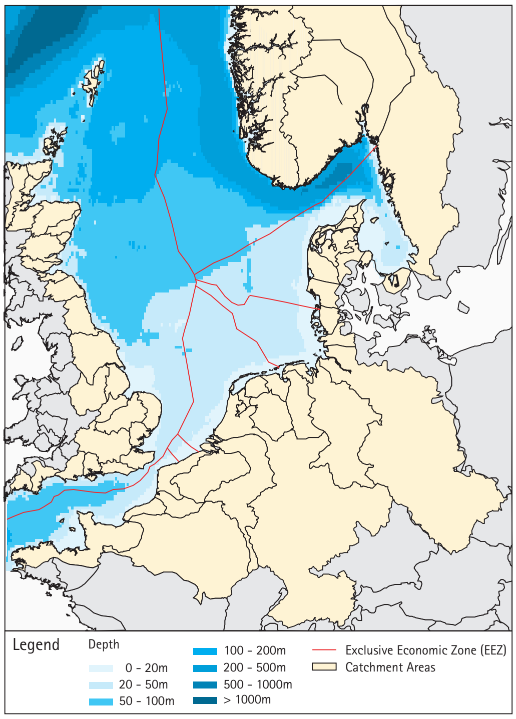


Figure 1.2: Bottom topography and catchment areas of the Greater North Sea (Source: OSPAR Commission)

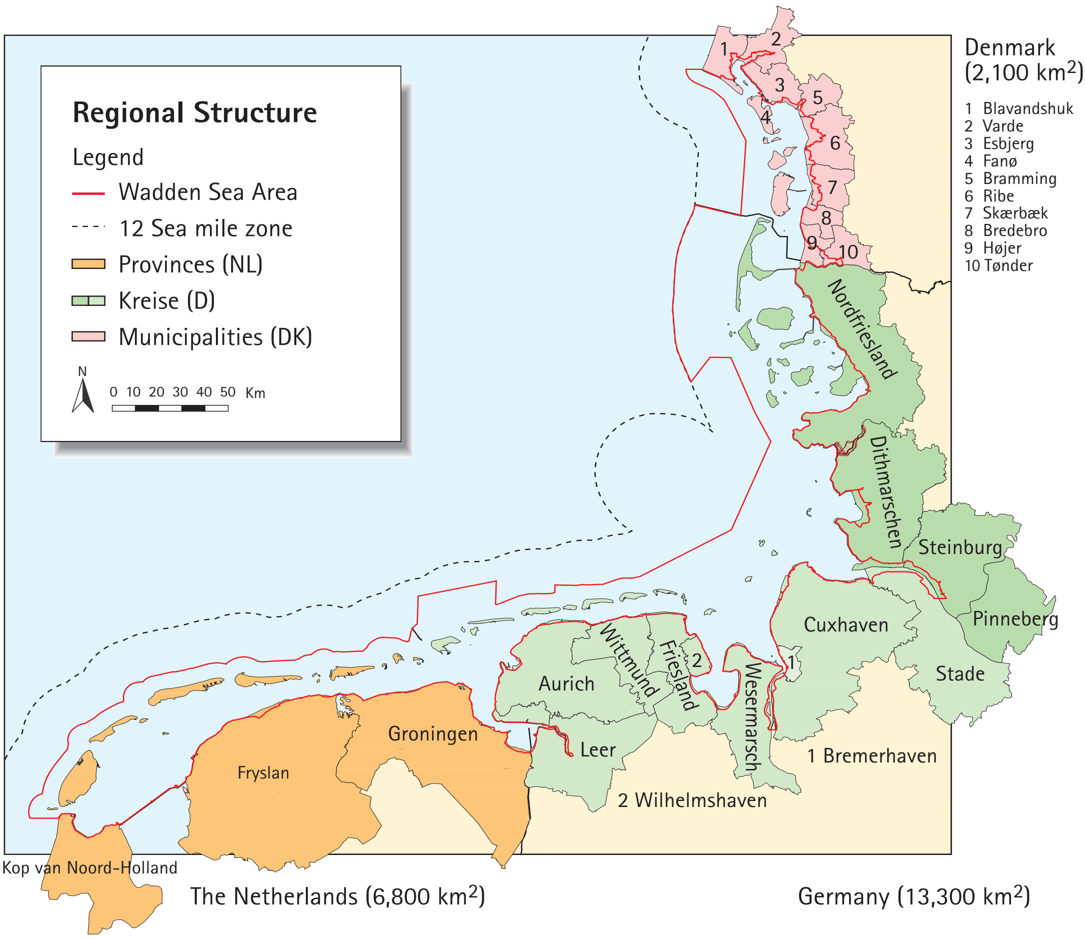


Figure 1.3: The Wadden Sea and its regional structure (from Prognos, 2004)

Regional Structure: 3.7 mill. inhabitants; 6 regional centers (Bremerhaven, Wilhelmshaven, Emden, Groningen, Leeuwarden, Esbjerg); 22,000 km^2 area (60% Germany, 31% Netherlands 9% Denmark); mainly rural structure with low population density (141 inhabitants per km^2).

1.2 Protection and Management

Harald Marencic
Karel Essink

1.2.1 Trilateral Cooperation

The first trilateral Danish-German-Dutch Governmental Conference on the Protection of the Wadden Sea was held in 1978 in The Hague and the 10th Ministerial Conference will be held on the Dutch island of Schiermonnikoog on 3 November 2005.

The formal basis of the Cooperation is the 'Joint Declaration on the Protection of the Wadden Sea' signed at the Third Wadden Sea Conference in Copenhagen in 1982. The Joint Declaration is a declaration of intent of the three Wadden Sea countries to consult each other in order to coordinate their activities and measures to implement a number of legal instruments with regard to the comprehensive protection of the Wadden Sea region as a whole including its fauna and flora. In 1987, the Common Wadden Sea Secretariat was established to facilitate and support the Cooperation.

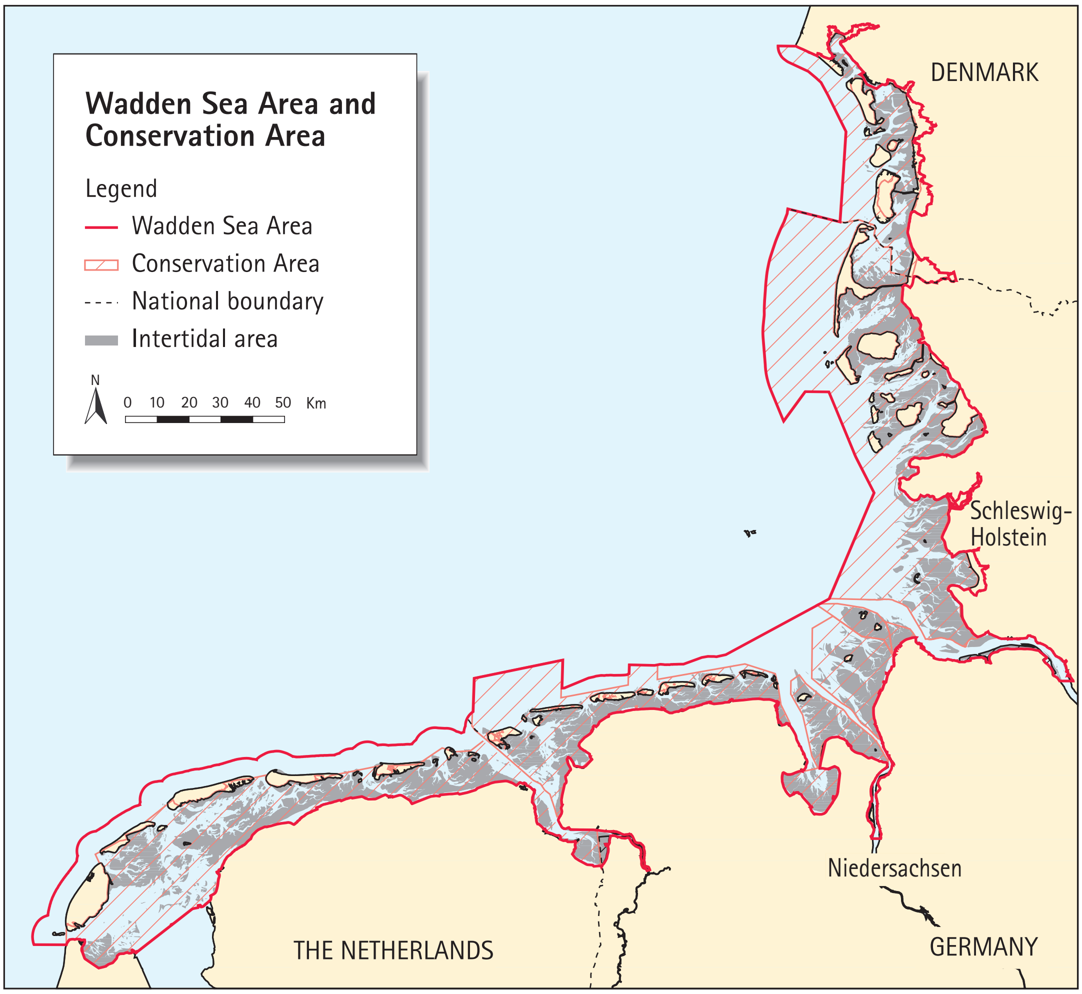
The three countries also concluded the 'Agreement on the Conservation of Seals in the Wadden Sea' in 1990, which is a regional agreement under the Convention for the Conservation of Migratory Species of Wild Animals (CMS, Bonn Convention).

Since 1997, the arrangements of the Wadden Sea Cooperation have been embedded in the framework of the Trilateral Wadden Sea Plan, which entails policies, measures, projects and actions agreed upon by the three countries. The Plan is a statement of how the three countries envisage the future coordination and integration of management of the Wadden Sea Area and of the projects and actions that must be carried out to achieve the commonly agreed Targets (Trilateral Wadden Sea Plan, 1997).

1.2.1.1 Size and delimitation

The Wadden Sea Area is, in general terms, the area seaward of the main dike (or, where the main dike is absent, the spring-high-tide-water line, and in the rivers, the brackish-water limit) up to 3 nautical miles from the baseline or the offshore boundaries of the Conservation Area. Additionally, some adjacent inland marsh areas of the Denmark and Schleswig-Holstein are part of the Wad-

Figure 1.4:
Map of the Wadden Sea Area and Conservation Area



den Sea Area (Figure 1.4) After the extensions of the Danish Wadden Sea Wildlife and Nature Reserve in 1998, the Schleswig-Holstein Wadden Sea National Park in 1999, and the Hamburg Wadden Sea National Park and Niedersachsen Wadden Sea National Park in 2001, the delimitation of the Trilateral Cooperation Area and the Conservation Area was adapted in 2001 (Esbjerg Declaration, 2001) because parts of the national parks of Schleswig-Holstein and Niedersachsen exceeded the three nautical mile line.

The Conservation Area consists of the Dutch National Planning Decree area ('Planologische Kernbeslissing', PKB), the three German National Parks and the Danish Wildlife and Nature Reserve.

The Wadden Sea Area covers an area of about 14,700 km²; the Conservation Area is about 11,200 km² (Table 1.1).

1.2.1.2 Shared Principles and Targets

The Guiding Principle of the trilateral Wadden Sea Cooperation is 'to achieve, as far as possible, a natural and sustainable ecosystem in which natural processes proceed in an undisturbed way' (Esbjerg Declaration, 1991, § 1). In addition, seven Management Principles were adopted which are fundamental to decisions concerning the protection and management of the Wadden Sea Area (Esbjerg Declaration, 1991, § 3).

The trilateral conservation policy and management is directed towards achieving the full scale of habitat types which belong to a natural and dynamic Wadden Sea. Each of these habitats needs a certain quality (natural dynamics, absence of disturbance, absence of pollution), which can be reached by proper conservation and management. The quality of the habitats is to be maintained or improved by working towards achieving Targets agreed upon for six habitat types: Salt Marshes, Tidal Area, Beaches and Dunes, Estuaries, Offshore Area and Rural Area. Targets for the quality of water and sediment are valid for all habitats. In addition, supplementary Targets on birds and marine mammals were adopted, as well as Targets for landscape and cultural aspects (Trilateral Wadden Sea Plan, 1997).

For each Target category, trilateral policy and management and proposals for trilateral projects and actions necessary for the implementation of the Targets are included in the Trilateral Wadden Sea Plan. The trilateral policy and management is the core of the agreements on the common protection and management of all relevant uses and activities. An assessment on the progress in implementation of the Targets is given in chapter 15.

Table 1.1: Size of the Conservation Area and Wadden Sea Area (km²). *Because of the disputed area in the Ems estuary, the figures for NL and FRG are approximate.

	Conservation Area	Wadden Sea Area
Denmark	1,250	1,500
Germany*		9,050
Schleswig-Holstein Nat. Park	4,410	
Hamburg Nat. Park	137.5	
Niedersachsen Nat. Park	2,777	
Nds.: NSG Ems, Elbe	34	
The Netherlands*	2,600	3,900
Disputed Area (NL, FRG)		250
Trilateral	**11,208.5**	**14,700**

Targets – Trilateral Wadden Sea Plan (1997)

Landscape and Culture

Identity – to preserve, restore and develop the elements that contribute to the character, or identity, of the landscape.
Variety – to maintain the full variety of cultural landscapes, typical for the Wadden Sea landscape.
History – to conserve the cultural-historic heritage.
Scenery – to pay special attention to the environmental perception of the landscape and the cultural-historic contributions in the context of management and planning.

Water and Sediment

A Wadden Sea which can be regarded as a eutrophication non-problem area.
Background concentrations of natural micropollutants in water, sediment and indicator species.
Concentrations of man-made substances as resulting from zero discharges.

Salt marshes

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 surface is not reduced.
An improved natural vegetation structure, including the pioneer zone, of artificial salt marshes.

Tidal Area

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.
A favorable food availability for migrating and breeding 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.

Estuaries

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

Offshore Area

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 harbor porpoise.

Rural Area

Favorable conditions for flora and fauna, especially migrating and breeding birds.

Birds

Favorable conditions for migrating and breeding birds:
- a favorable food availability,
- a natural breeding success,
- sufficiently large undisturbed roosting and molting area
- natural flight distances.

Marine Mammals

Viable stocks and a natural reproduction capacity of the common seal, grey seal and harbor porpoise in the tidal areas and the offshore zone.

1.2.1.3 Trilateral Monitoring and Assessment Program

The Trilateral Monitoring and Assessment Program (TMAP) is the common monitoring program for the Wadden Sea carried out by the Netherlands, Germany and Denmark in the framework of the Trilateral Wadden Sea Cooperation.

The aim of the TMAP is to provide a scientific assessment of the status and development of the Wadden Sea ecosystem and to assess the status of implementation of the trilateral Targets of the Wadden Sea Plan. After a pilot phase which started in 1994, a Common Package of monitoring parameters including the associated data management has been implemented since 1997 (Stade Declaration, 1997). Joint monitoring programs for breeding and migratory birds and seals had already been trilaterally implemented since 1989 and 1992, respectively, and are also part of the TMAP.

1.2.2 International Protection Regimes

1.2.2.1 Particularly Sensitive Sea Area

In 2002, the Wadden Sea was designated as a Particularly Sensitive Sea Area (PSSA) by the International Maritime Organization (IMO) (Figure 1.5). The purpose of the PSSA is to send a strong signal to and increase the awareness of the international shipping community regarding the particular sensitivity of the Wadden Sea Area.

The area designated as a PSSA is the marine area of the Wadden Sea Conservation Area, comprising the Wadden Sea national parks in Germany and the Wadden Sea nature protection areas in Denmark and the Netherlands. The PSSA covers an area of approximately 13,000 km², the major shipping routes have been excluded from the designation.

The PSSA sea does not limit shipping in the area nor the use of the Wadden Sea harbors. The designation of the PSSA Wadden Sea is seen as a recognition of the extensive regime of the national and international protective measures already in

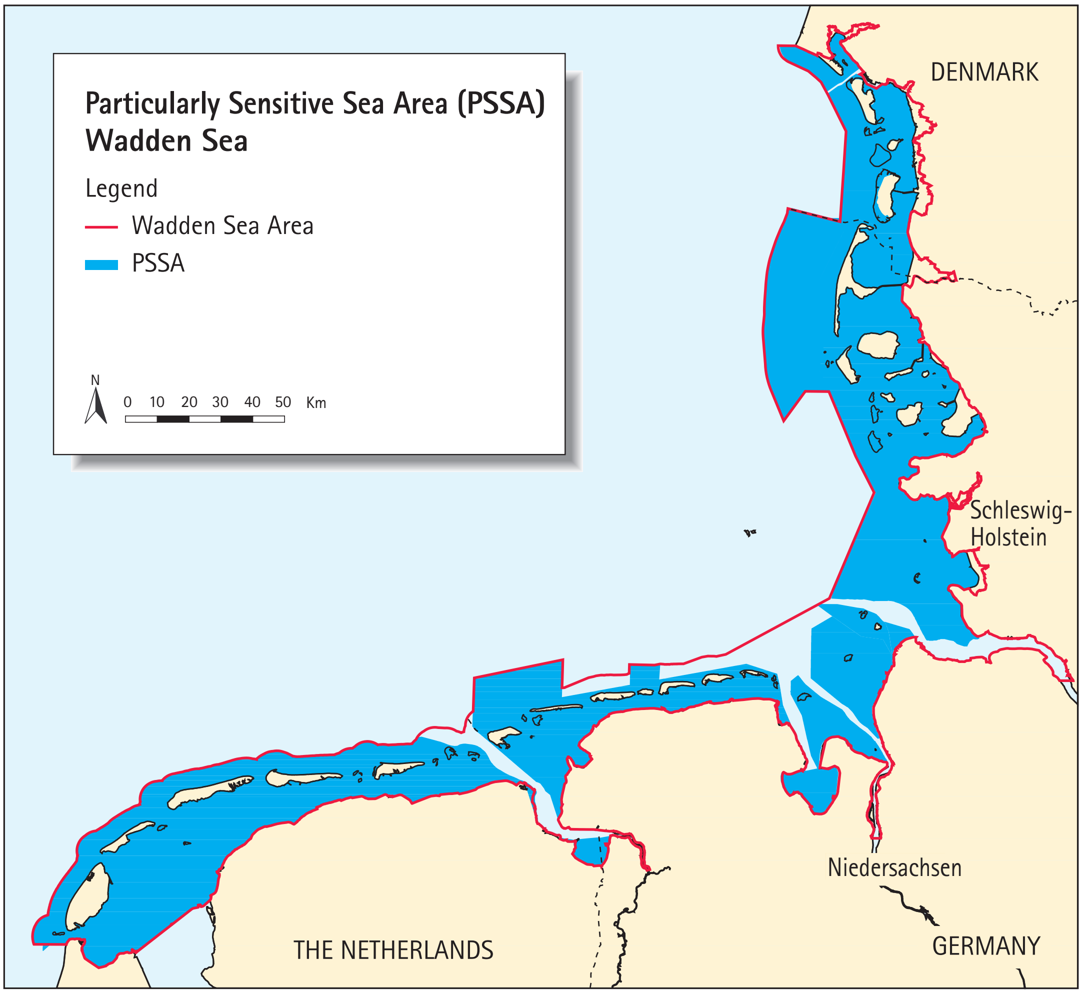


Figure 1.5: Map of the Particularly Sensitive Sea Area (PSSA) Wadden Sea as designated by the International Maritime Organization (IMO) in 2002.

place in the Wadden Sea and adjacent the North Sea. Examples are the MARPOL Special Areas against discharge of oil and garbage, routing systems making certain routes compulsory for ships carrying hazardous goods and compulsory reporting for ships.

1.2.2.2 EC Directives

Birds and Habitats Directive

The Council Directive 79/409/EEC on the conservation of wild birds was adopted in 1979 (Birds Directive) and aims at the protection of all species of naturally occurring birds in the territory of the member states. According to the Birds Directive, member states must classify the most suitable territories for the conservation of the species listed in the Annex 1 of the Directive, as 'Special Protection Areas' (SPAs). Basically, the entire Wadden Sea Area except the main shipping lanes and adjacent offshore areas have been designated as SPA (Figure 1.6).

The Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (Habitats Directive) adopted in 1992, complements the 1979 Birds Directive. It has the aim of ensuring that biodiversity is maintained through conservation of important, rare or threatened habitats and the habitats of certain species.

In the framework of the Habitats Directive a coherent ecological network, called NATURA 2000, is being established. NATURA 2000 will consist of Special Areas of Conservation (SACs) designated according to the Habitats Directive, and the SPAs of the Birds Directive.

Major parts of the Wadden Sea Area have already been included in NATURA 2000. Since the 1999 QSR, further areas have been nominated as SAC in the framework of the Habitats Directive and as SPA in the framework of the Birds Directive entailing a substantial extension of the Natura 2000 as a result of the extension of the German national parks in 1999 and 2001. An overview of the Habitats Directive areas in the Wadden Sea is shown in Figure 1.7 (status September 2004). Because the nomination process has not yet been concluded in Germany, the delimitation of Habitats Directive areas may change during 2005.

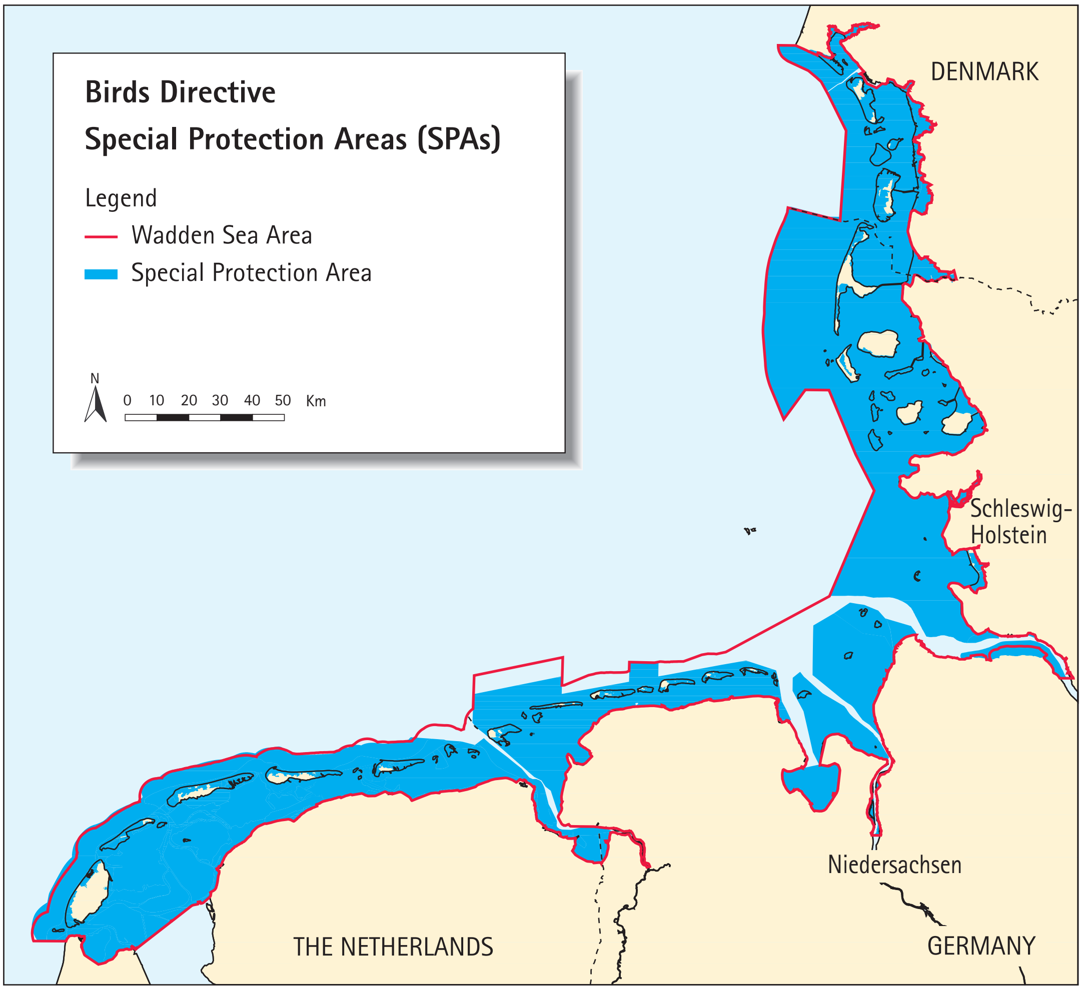


Figure 1.6: Special Protection Areas (SPAs) under the EC Birds Directive in the Wadden Sea Area (status September 2004).

Water Framework Directive

The Council Directive 2000/60/EC on establishing a framework for Community action in the field of water policy (Water Framework Directive, WFD) was enacted in December 2000. It aims at a coordination of all water-related measures on a European level. The key elements of the WFD include the protection of all waters, surface and ground waters in a holistic way and achieving good quality ('good ecological status') by 2015. A first analysis of pressure and impacts has to be reported by the member states in 2005.

A River Basin Management Plan has to be prepared by 2009 based on the results of an operational monitoring program (to be established by 2006). River management plans are to be reviewed every 6 years.

The Wadden Sea has been assigned to six different River Basin Districts (RBDs) differentiated in coastal and transitional waters. These RBDs are the main management units of the WFD and cover all types of surface and ground waters. Coastal waters covers the areas up to 1 sm from the baseline and with regard to the chemical status also the territorial waters (up to 12 sm) (Figure 1.8).

The Esbjerg Declaration 2001 underlines the importance of close cooperation with regard to the Wadden Sea Area when implementing the Water Framework Directive.

1.2.2.3 Other International Conventions and Programs

The Wadden Sea countries are contractual parties to a number of international agreements, conventions and treaties, in particular, the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention) (Figure 1.9), the Convention on Biological Diversity (CBD), the Convention on the Conservation of Migratory Species of Wild Animals (CMS, Bonn Convention) also covering the Agreement on the Conservation of Seals in the Wadden Sea (Seal Agreement), the Agreement on the Conservation of African-Eurasian Waterbirds (AEWA) and the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) and the

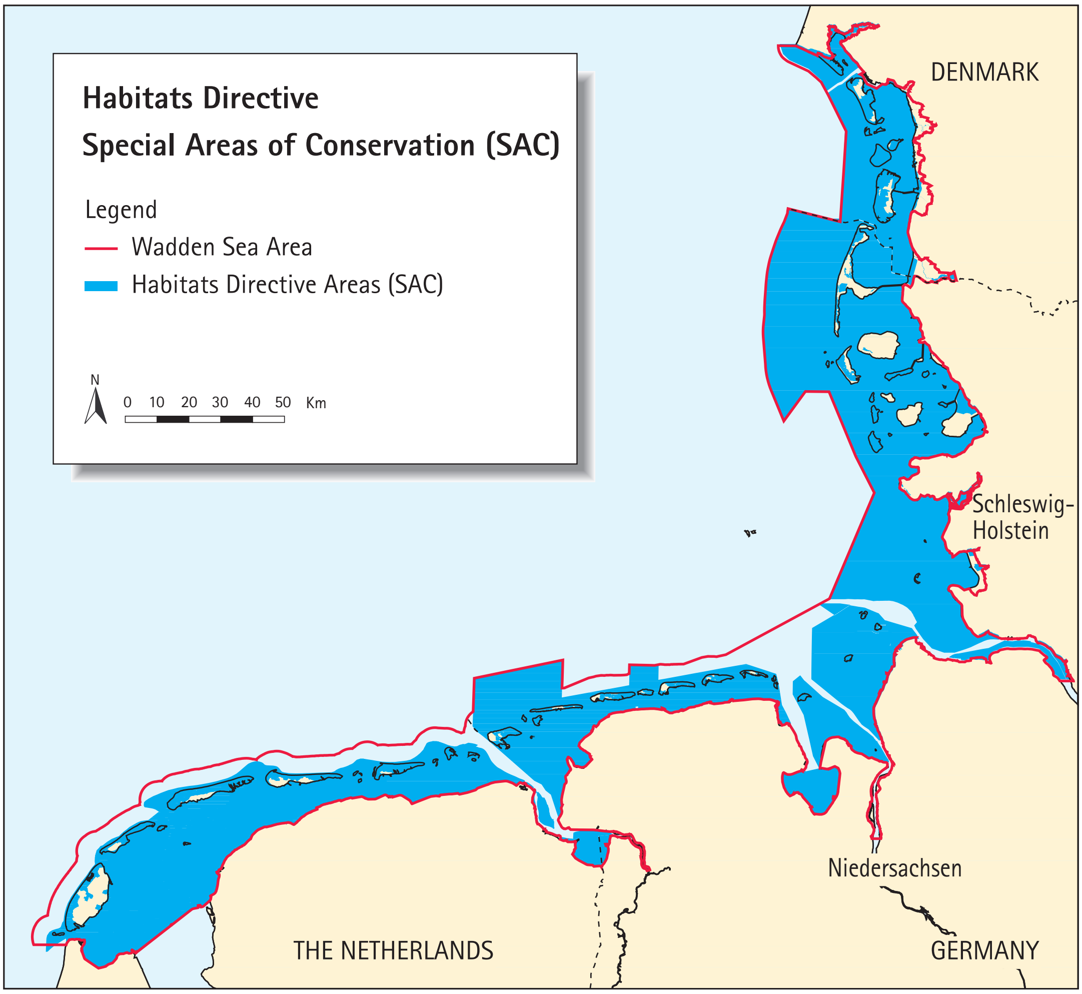


Figure 1.7: Special Areas of Conservation (SAC) under the EC Habitats Directive in the Wadden Sea Area (with the current status of nomination, September 2004).

Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention). The German and Dutch parts of the Wadden Sea have been designated as Man and Biosphere (MAB) Reserves under the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Due to the strong interactions between the Wadden Sea and the adjacent North Sea, the trilateral policy and management regarding pollution is closely related to the OSPAR and the North Sea Conferences.

At the 5th North Sea Conference in Bergen 2002, the North Sea ministers agreed to implement an ecosystem approach to management which was to be guided by a conceptual framework (Bergen Declaration, 2002). Part of this framework are ecological quality objectives (EcoQOs), to be used as a tool for setting clear operational environmental objectives directed towards specific management and serving as indicators for the ecosystem health.

The development of a coherent and integrated set of EcoQOs is currently undertaken by OSPAR and the International Council for the Exploration of the Sea (ICES), in coordination with the development of marine indicators in the European Environment Agency (EEA) and environmental objectives in the EC Water Framework Directive. For the North Sea, a pilot project on the development of EcoQOs for a selected set of ecological quality elements was formulated (Bergen Declaration, 2002).

Ecological quality objectives relevant for the Wadden Sea relate to the proportion of oiled common guillemots among those found washed ashore, the level of imposex in female dog whelks, phytoplankton indicator species for eutrophication and winter nutrient concentrations (dissolved inorganic nitrogen and phosphorus).

1.2.3 National regimes

In the 1999 QSR, a comprehensive overview of the national protection and management regimes was given. In the following sections, the focus has been placed on the main developments since then.

1.2.3.1 The Netherlands

Because the European Commission considered the implementation of the Birds- and Habitats Direc-

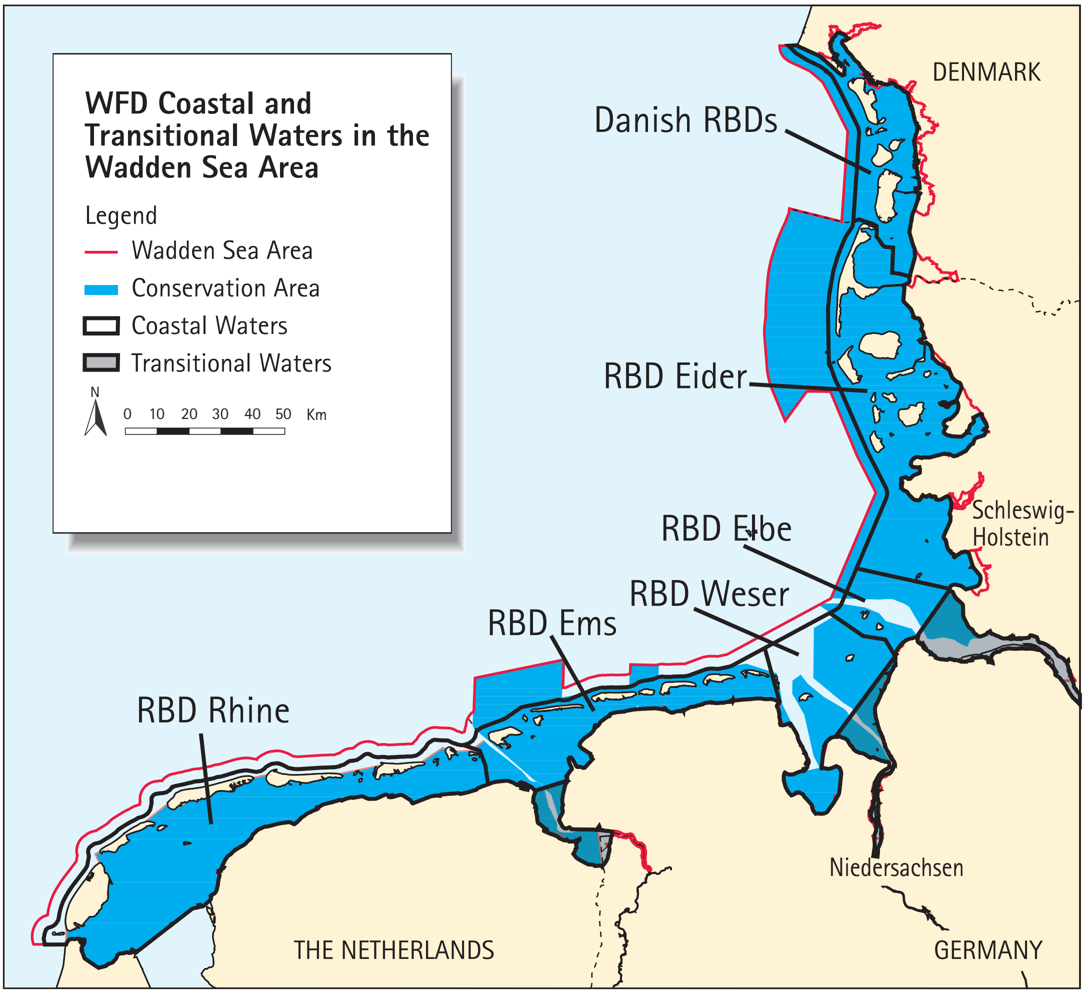


Figure 1.8: Coastal and transitional waters of the River Basin Districts (RBDs) of the Water Framework Directive in the Wadden Sea Area (only seaward parts of the RBDs are shown).

tive in The Netherlands as insufficient, the Nature Protection Act ('Natuurbeschermingswet') needs to be revised. A new Nature Protection Act was accepted by the 2nd Chamber of Parliament in May 2004 and by the 1st Chamber in January 2005. The revision also pertains to the new roles of central government, provinces and communities in the granting of licenses. The National Planning Decree ('Planologische Kernbeslissing', PKB) for the Wadden Sea sets out the general policies for all human uses in the Wadden Sea Conservation area. In June 2005, a new policy plan will be published. Main policy issues also concerns gas drilling and shellfish fisheries in the Wadden Sea.

1.2.3.2 Germany

Since the Stade Conference 1997, the acts on the three German national parks have been amended entailing a substantial extension of the German Wadden Sea Conservation Area and partly new regulations.

Niedersachsen

The Niedersachsen Wadden Sea National Park Act was amended in May 2001. The National Park was extended seaward partly beyond the three nautical mile line off the islands of Borkum and Baltrum, it includes areas previously outside the National Park in the Ems-Dollard estuary (Rysumer Nacken), the nature reserve in the Dollard and a transition zone between the salt marsh and the geest south of Cuxhaven. The National Park also covers the large majority of the islands. Compared to the previous National Park area, well defined parts on the islands consisting of built-up and intensively used areas have been excluded and the boundaries redefined.

The zoning scheme within the National Park has been partly revised. Zone 1 was extended on most of the islands to also include the primary dune areas on the eastern parts of the islands. Also in the tidal area, zone 1 was extended. The recreational zone was partly extended. Some intensively used parts of the recreational zone was excluded from the National Park.

The area of the National Park has, as a result of the amendment of the act, increased with about 400 km² up to 2,777 km² (277,000 ha).

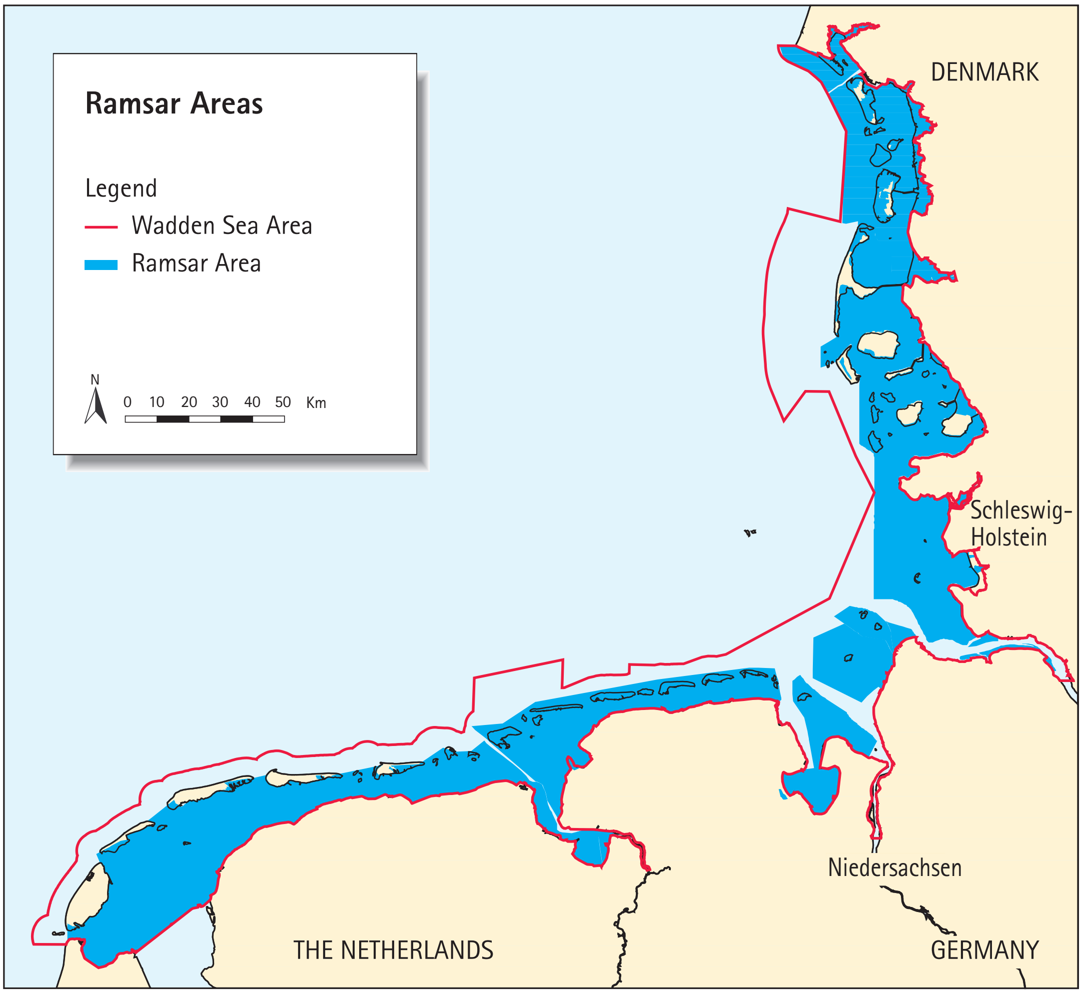


Figure 1.9: Wetlands of International Importance according to the Ramsar Convention in the Wadden Sea Area.

Hamburg

The Hamburg National Park Act was amended in April 2001. The act entails a seaward extension of the national park up to 3 nautical miles. The extension has increased the area of the national park by approximately 2,050 ha up to now 13,750 ha. The amendment entails both a harmonization between the National Park law and the Habitats Directive and new specifications for fishing regulations within the National Park resulting in the extension of the already existing zero-use zone up to more than 75 % of the National Park area. The act also entails stricter regulations of certain recreational activities such as kite flying and the traditional collecting of mushrooms.

Schleswig Holstein

In December 1999, an amended national park law was enacted for the Schleswig-Holstein Wadden Sea National Park. The amended national park law entails a further specification of objectives, extension of the area under protection, and a new zoning scheme.

The national park was extended seaward up to three nautical miles in the southern part of the national park and up to 12 nautical miles in the northern part, which includes the whale protection area. The National Park covers about 4,410 km^2 (441,000 ha) which is an extension of about 1,700 km^2. The whale protection area is approximately 1,240 km^2.

The zoning scheme of the National Park was re-designed entailing a two-zone system. Zone 1 comprises, in principle, coherent tidal basins and covers about 36% of the area. Public access is prohibited with the exception of, for example, near-shore tidal areas, tidal flat walking routes and commercial fishery as stipulated in Section 6 (2) of the law. Within zone 1 an area south of the Hindenburger dam of 12,400 ha (about 3% of the National Park) was designated as a zone in which all resource use has been fully prohibited. Navigation is only allowed in the zero-use zone on the marked shipping lanes. The remaining area of the National Park is zone 2, including the whale protection area off Sylt and Amrum. Additionally, it can be stated that hunting, which prior to the new amendment was largely phased out, is now completely prohibited within the National Park. The same holds for wind turbines.

1.2.3.3 Denmark

The revised Statutory Order for the Danish Nature and Wildlife Reserve (the Danish section of the Conservation Area) was enacted in 1998 (for details see 1999 QSR) implementing the Stade Declaration (1997) and Wadden Sea Plan (1997). On the regional level, this was done within the framework of the regional physical planning. The two county councils of Ribe and South Jutland endorsed a supplementary planning document 'The Wadden Sea and its surroundings' to the regional plan in 2001.

1.3 Reference Areas

Adolf Kellermann
Kai Eskildsen

1.3.1 Introduction

The term 'reference area' is commonly used for sites representing certain conditions for purposes of monitoring or research. In the framework of the Trilateral Cooperation, they are first mentioned in context of initiating the Trilateral Monitoring and Assessment Program (TMAP) in the Esbjerg Declaration of 1991. There, it was agreed to designate 'sufficiently large areas, spread evenly over the Wadden Sea, where all exploitation and all disturbing activities are banned and which can serve as reference areas for scientific purposes' (Esbjerg Declaration, 1991, § 33.3). At the Esbjerg Conference 2001, the ministers recalled 'the decision taken at the 6th Wadden Sea Conference to designate reference areas, and in this respect, to welcome the designation of a reference area without resource exploitation in the Schleswig-Holstein Wadden Sea 1999 in addition to the Danish zero use reference area designated in 1982, and the Hamburg zero-use area designated in 1990, and the anticipated designation of a reference area in the Dutch Wadden Sea' (Esbjerg Declaration, 2001; §11).

1.3.2 Definition

Reference areas represent certain standards (*e.g.* for libraries), conditions (*e.g.* for medical purposes), states or stages (*e.g.* ecological stages). By definition, they are designed to serve monitoring and research. Thus, their inventory is thought to be representative for larger units.

According to the Ministerial Declaration, Esbjerg 1991, areas serving as reference areas for scientific purposes must

- have a sufficiently large size;
- be spread evenly over the Wadden Sea;
- be free of exploitation and disturbances ('zero-use zone').

It is obvious that reference areas were to be established to serve monitoring and research in the Wadden Sea. The relation has been further specified by the Trilateral Monitoring and Expert Group (TMEG), installed to develop the conceptual framework of the Trilateral Monitoring and Assessment Program (TMAP) in 1992.

The 1999 QSR (chapter 6.4.7) stated that reference areas meet the requirements of scientific research and monitoring as a basic instrument for nature protection management and politics. A precondition for measurement and assessment of the effects of anthropogenic influence on natural ecosystem structures and processes is the comparison of areas with and without human resource utilization. The proper assessment of data and results of the TMAP depend on the existence of reference areas (TMEG, 1993). The necessity of reference areas – the only sites where 'undisturbed' ecosystem processes can be studied - has also been stressed by Colijn *et al.* (1995), especially for the description and understanding of changes in the abundance of species and the assessment of sustainable development.

The 1999 QSR concluded that the above listed features are only represented by entire tidal basins, stretching from the salt marshes to the ebb delta opening out into the adjacent North Sea. Reise (1992, 1994) proposed a concept for such 'core areas' or 'ecological priority areas' distributed over the Wadden Sea.

1.3.3 Status

1.3.3.1 The Netherlands

In the Dutch Wadden Sea, reference areas according ED 1991, § 33.3 have not yet been designated. As part of the new shellfish fishery policy and included in the coming National Planning Decree ('Planologische Kernbeslissing, PKB') of an area south of the islands Rottumerplaat and Rottumeroog (about 6,500 ha; 2.5% of the Dutch Wadden Sea) is proposed for designation as a reference area (Figure 1.10). This area does not include the entire tidal basin but comprises all important ecological elements.

A formal decision for the designation as reference area will to be taken in 2005 after discussing the consequences for existing uses like shrimp fisheries. The area is already closed for shellfish fisheries since 1993.

1.3.3.2 Germany

Within the core zone of the National Park of Schleswig-Holstein, an area of 12,500 ha called 'Hörnum Tief' south of the Hindenburg dam was designated as a 'zero-use zone' in 1999 which covers about 3% of the National Park area (Figure 1.10). In this area, all resource use including fishery has been fully prohibited. Navigation is only allowed in the zero-use zone on the marked shipping lanes.

In the 'Hörnum Tief' area, regular surveys of seals, roosting and breeding birds, blue mussel beds, eelgrass and marcoalgae are carried out as part of the TMAP. Since 2001, pelagic fish monitoring has been carried out at three stations in the reference area in addition to the three stations in the Meldorf Bight where fish monitoring has been carried out since 1991. Since 2002, an automatic recording device has been installed in the reference area during the period May – November to collect data on data, water level, hydrology and turbidity. Also in 2002, a benthos mapping was carried out in the Wadden Sea similar to the survey in 1987-1993 also covering the zero-use-area.

Within the National Park of Hamburg, an area of about 10,400 ha has been protected as a 'zero-use zone' mainly since 1990. In this area, all resource use has been fully prohibited. Navigation is only allowed in the zero-use zone on the marked shipping lanes. Fishery is prohibited with the exception of shrimp fishery in these shipping lanes (100 m width). The area covers about 76% of the National Park area (Figure 1.10). An integrated monitoring program has been established in the Hamburg National Park according to the reporting requirements for the TMAP, the EC Birds and Habitats Directives. It consists of monitoring breeding and migratory birds, common seals, macrozoobenthos, salt marsh and dune vegetation (Umweltbehörde Hamburg, 2001).

In Niedersachen, large areas within the National Park *e.g.* the islands Memmert and Mellum, and tidal flats, the 'Hohe Knechtsand' are without any resource use and disturbances by recreational activities. However, theses zero-use areas have not officially been designated as reference areas for scientific purpose.

1.3.3.3 Denmark

In 1982, a reference area was designated around the island of Langli which is free of exploitation and disturbances and fulfills the definition of a reference area. It covers the tidal flat (about 800 ha, about 1% of the Danish Wadden Sea) between Langli and the Skallingen peninsula. In addition, the island of Langli (80 ha) and a zone 300 m north, east and south of the island are closed to the public for most of the year (September 16 - July 15). The area represents typical tidal and island habitats covering one tidal basin (Figure 1.10).

Since 1983, regular monitoring of breeding and migratory birds has been carried out on Langli and is included in the TMAP (breeding birds since 1991, spring tide counts of migratory birds since 1994). A field station on Langli was run from 1983 to 2002, manned by 1-2 persons over the whole year.

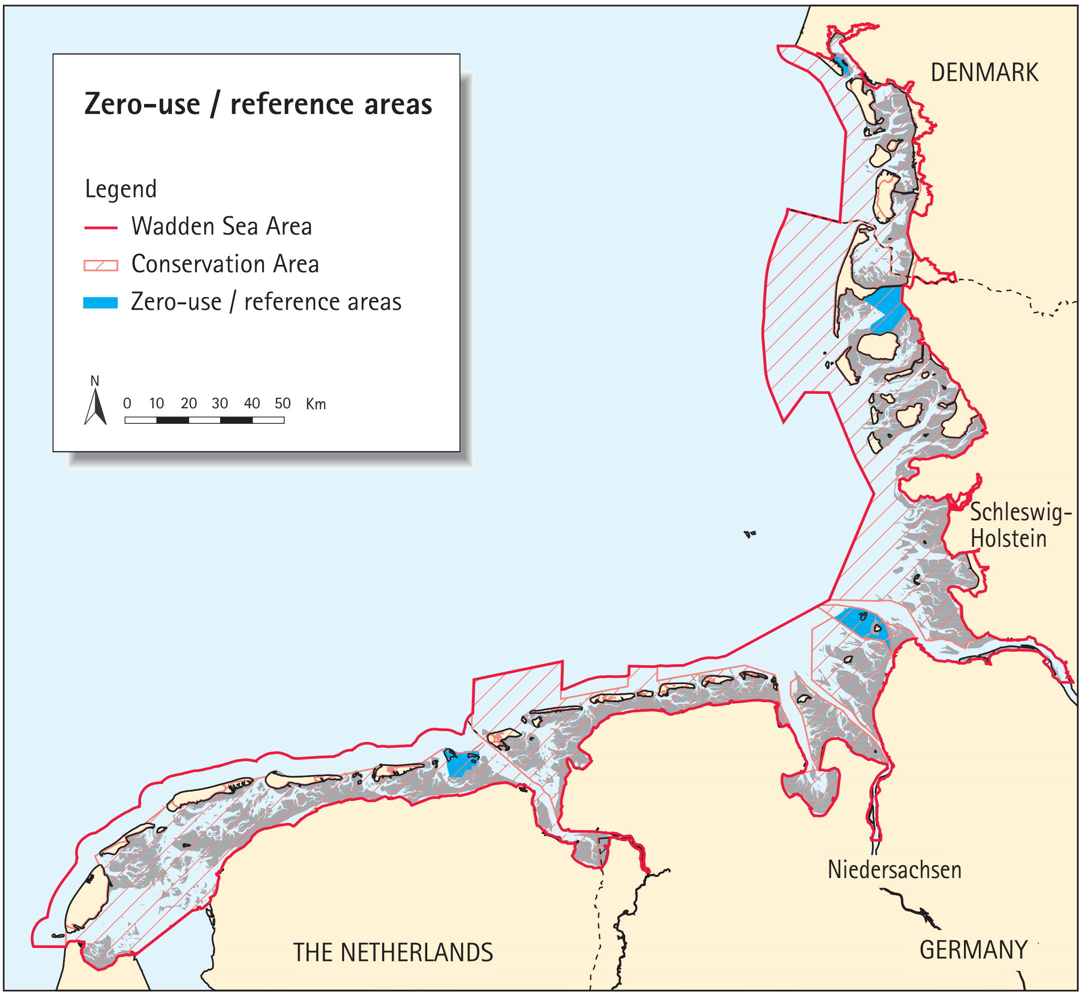


Figure 1.10: Map of zero-use areas / reference areas in the Wadden Sea. Note: The designation of the marked site in The Netherlands as reference area is under discussion.

Since 2002, monitoring has been carried out during regular visits. In addition, biological and geological research studies have been carried out on Langli by universities and other institutes. The intertidal part of the reference area is also a site of the blue mussel monitoring program.

1.3.4 Conclusion and recommendations

The precondition for reference areas in the sense of the Esbjerg Declarations 1991 and 2001 is the designation of zero-use-areas. This has been done in Denmark, Schleswig-Holstein and Hamburg by legislation as shown above. In line with the 1999 QSR, it has to be concluded that existing zero-use-areas do not yet meet the scientific approach in which entire tidal basins serve as reference areas.

To fulfill the obligations of the Esbjerg Declarations 1991 and 2001 more zero-use-areas are recommended. These areas should stretch from the salt marshes to the ebb delta and have to be spread over the whole Wadden Sea. Then, and only then, can these areas serve as reference areas for monitoring and research.

Furthermore it is obvious that there is a necessity to control the zero-use in these areas in addition to the parameter set of the TMAP Common Package.

Table 1.2: Overview of zero-use areas in the Wadden Sea and their status in the light of Esbjerg Declaration 1991 and 2001. For The Netherlands, a proposal for designation of a reference areas is given in the new PKB, a final decision will be taken in 2005. For Niedersachen, the zero-use areas are not listed because they have not officially been designated as reference areas.

	Langli (Denmark)	Hörnum Tief (Germany – Schleswig-Holstein)	Hamburgisches Wattenmeer (Germany–Hamburg)	Rottumeroog / Rottumerplaat (The Netherlands) (proposal)
Size and area	800 ha Entire tidal basin.	12,500 ha Approx. 50% of tidal basin	10,400 ha	6,500 ha Part of tidal basin.
Typology	Tidal flats and island habitats.	Back-barrier tidal flats.	Open Wadden Sea area.	Back-barrier tidal flats.
Sub-ecosystems included	Tidal basin with silt, mixed, sandy flats, creeks and deep; island with dunes and salt marsh and mainland salt marsh.	Inner tidal basin with silt, mixed, sandy tidal flats and tidal creek systems, island and mainland salt marshes and primary dunes.	Estuary flats with silt, mixed, sandy tidal flats and tidal creek systems; island salt marshes and primary, white and grey dunes.	Small uninhabited islands, primary dunes, salt marsh, tidal basin with sandy flats.
Legal basis	Wildlife Reserve Act 1998 (Art. 7)	National Parks Act (Art. 4)	National Parks Act (enacted 1990, amended 2001) (Art. 2 to 5)	Proposed for designation in PKB 2005-2015
Year of designation	1982	1999	1990	Planned in 2005
Reasons for designation	Safeguarding the dynamics of flora and fauna, natural processes and structural diversity.	Safeguarding development free of human intervention, as well as natural structural diversity and the dynamics of processes.	Safeguarding the dynamics of natural processes and structural diversity.	Safeguarding the natural dynamic development of habitats and species diversity.
Resource uses	None	None	None	None
Zero-use area	Conform ED 1991	Conform ED 1991	Conform ED 1991	Conform ED 1991
Public access, shipping, fishing	Tidal flats between the island Langli and Skallingen (mainland) are closed for the public. Langli is closed for the public from 16 September to 15 July.	Shipping only along navigational routes, entry near coastline.	Shipping and shrimp fishing only along navigational routes; in some cases, entry close to islands (e.g. Kleiner Vogelsand) or navigation on two marked routes	Already closed for shellfish fisheries. Shrimp fisheries will be forbidden.
Monitoring program and parameters	TMAP Birds, blue mussels.	TMAP Fish fauna, measuring pole, theme-based mapping.	TMAP Macrofauna, seals, birds.	TMAP Blue mussels, fish birds, seals
Reference area and purpose	Yes Undisturbed development of a tidal basin, which represents a typical 'small scale' Wadden Sea ecosystem.	Yes Purpose under under discussion.	Yes Undisturbed development of high tidal flats and semi-natural dune islands including their biological communities.	Yes Undisturbed development of a tidal basin, which represents a typical 'small scale' Wadden Sea ecosystem.
Representative for	Tidal flats, island habitats.	Back-barrier tidal flats.	Mesohaline estuary flats and partly tidal creeks, salt marshes.	Back-barrier tidal flats.

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2. Human Activities

Jacobus Hofstede
Karl Hähne
Albert Oost
Thorsten Piontkowitz
Karen Raagaard
Henni Schans
Frank Thorenz
Christiane Gätje
Karsten Laursen
Hugo Eekhof
Thomas Borchardt
Harald Marencic
Karel Essink

2.1 Coastal Defense

Jacobus Hofstede
Karl Hähne
Albert Oost
Thorsten Piontkowitz
Karen Raagaard
Henni Schans
Frank Thorenz

(Photo: J. Hofstede)

2.1.1 Introduction and transnational aspects

This chapter concentrates on new developments in coastal defense since 1999. For a more comprehensive overview of national responsibilities and measures, the reader is referred to the 1999 Wadden Sea Quality Status Report (de Jong *et al.*, 1999) and to the report of the trilateral working group 'Coastal Protection and Sea Level Rise' (CPSL, 2001).

Coastal defense aims to safeguard coastal lowlands, their inhabitants and economic assets against the forces of the sea. It consists of coastal flood defense (protection against flooding) and coastal protection (protection against structural erosion). Storm surges do not stop at national borders. In recognition of this, a number of transnational cooperations among coastal defense authorities around the North Sea and the Wadden Sea have been initiated since 1999.

As an output of the 8th Trilateral Governmental Conference on the protection of the Wadden Sea (Stade Declaration, 1997), a trilateral expert group from the national coastal defense and environmental administration started to work on the topic 'Coastal protection and sea level rise' in 1999.

The expert group defined common understanding of processes in the Wadden Sea (morphology, biology and coastal defense). On the basis of this, for three scenarios (sea level rise of 10 cm, of 25 cm and of 50 cm until 2050), impacts on selected physical, biological, and socio-economic parameters were investigated. A first screening of sustainable coastal defense measures (best environmental practices) to ensure present safety standards in the future was conducted. Finally, the expert group formulated several recommendations for policy, management and research (CPSL, 2001; Esbjerg Declaration, 2001).

A follow-up study (CPSL II) started in autumn 2003. In CPSL II, the work is focused on feasibility studies of integrated coastal defense solutions that maintain, in the long term, the existing safety standards and anticipate the expected impacts of sea level rise. At the same time, they should be beneficial or, at least, not negative, for natural assets, such as natural dynamics and habitat quality (see also CPSL, 2005).

In 1996, the leading coastal flood defense and coastal protection authorities around the North Sea initiated an informal forum, the North Sea Coastal Management Group (NSCMG). During yearly meetings transnational issues on coastal defense such as climate change and EU-regulations, are discussed.

As one NSCMG-activity, a consortium of national and regional coastal defense authorities around the North Sea started an INTERREG IIIB co-financed project 'COMRISK – common strategies to reduce the risk of storm floods in coastal lowlands' in 2002 (COMRISK, 2002). In five subprojects, different aspects of coastal flood defense and coastal protection (*e.g.*, national policies and strategies, public awareness and participation, national hydraulic boundary conditions) are evaluated. In addition, in four pilot areas *(e.g.* Ribe, Langeoog), state of the art coastal risk analyses are conducted. This project will be concluded in 2005.

2.1.2 The Netherlands

Dikes

Both the mainland and part of the islands are protected by dikes. Not much has changed since 1999. Currently research is being conducted to evaluate the current safety standards as set within the 'Wet op de Waterkering' (Coastal Defense Act, 1996). The salt marshes in front of the mainland dikes are protected and managed from a nature conservation perspective according to best environmental practice. In 2001 part of the summer polders (1.35 km^2) in the area 'Noord Friesland buitendijks' was turned into tidal marsh. If this is successful, there are plans to change another 8.75 km^2 of summer polders into tidal marsh.

The sandy coast

The Dutch Wadden Sea islands generally have broad beaches and dunes. These present the most important element of coastal protection on the North Sea coast of these islands. The Dutch coastal defense policy is based on the principle of dynamic maintenance, i.e. using sand nourishments to maintain the coastline. Building 'hard' man-made structures (*e.g.* groynes) is allowed in exceptional cases only. 'Hard' structures are present along 6 of the 155 km of the sandy coast of the inhabited islands.

Currently, there is discussion as to the exact position of the line of dunes on the barrier islands which should - together with the dikes on the Wadden Sea side - form a protective ring around the villages as stipulated by the Coastal Defense Act. Besides the protective ring around the villages, the coastline is maintained at its 1990 location. In the period 1991-2000, 23 million m^3 of sand was supplied to over 95.5 km of coastline. A large part of these nourishments are shoreface nourishments (applied below the low water line) which are, in terms of costs, more successful than beach nourishments. In 2003, the first subtidal channel wall nourishment was carried out in the Molengat tidal channel near Texel (J. Cleveringa, RIKZ, pers. comm.).

Since 1999 the salt marsh area has remained stable. The existing protection along the mainland marshes prevent the marshes from being eroded. The protection is being maintained in the most environmentally friendly way possible. Sediment deposition on these marshes by wind-driven transport or wash-over is allowed and sometimes encouraged. This could be an extra help in maintaining the island when sea level rise accelerates.

Trilateral policy and management

The interests of nature protection and sea defense measures will be further harmonized, taking into account that the safety of the inhabitants is essential. (WSP §§ 3.1.6; 5.1.2)

As a principle, it is prohibited to embank salt marshes and loss of biotopes through sea defense measures will be minimized. Reinforcement of existing dikes will be carried out on the location of existing dikes and, preferably, on the land side. (WSP §§ 3.1.7; 4.1.2; 5.1.6)

In general, clay for sea defense will be extracted behind the dikes. In special cases, i.e. where there is urgent and sudden need and if no other deposits behind the dikes are available, or if the extraction of suitable material is ecologically balanced, the extraction of clay may be allowed in front of the dike. In this case, the extraction shall be carried out in such a way that the environmental impact is kept to a minimum and permanent or long lasting effects are avoided and, if this is not possible, compensated. (WSP § 3.1.9)

Because the natural dynamics in the tidal area are directly related to coastal defense activities on the mainland coast, the islands and the offshore zone, future coastal protection policies will, as a principle, be based on these interrelationships. (WSP § 4.1.1)

The extraction of sand in the Conservation Area will be limited to the dredging and maintenance of shipping lanes. This sand can be used for, inter alia, sea defense purposes. In specific cases, sand may also be extracted for sea defense purposes. (WSP § 4.1.11)

Coastal management should aim at a natural dynamic development taking into account the necessity to protect the security of the inhabitants on the islands and safeguarding the stability and the infrastructure of the islands. (WSP § 5.1.5)

In case coastal protection is carried out, Best Environmental Practice will be applied. (WSP §§ 3.1.8; 5.1.7)

It is important to restore the natural dynamics. This could be done by e.g. by allowing sand drift and restoring natural dune vegetation, as far as coastal protection is not affected. (WSP § 5.1.9)

(Trilateral Wadden Sea Plan (WSP), 1997)

2.1.3 Germany: Niedersachsen

Dikes

In Niedersachsen, all coastal defense elements are defined in the Dike Act (NDG, 2004). After 1999, the reinforcement program for the main dikes was continued (ML, 1973; BRWE, 1997). The Ems storm surge barrier (Emssperrwerk) near Gandersum was finished in autumn 2003. As a result, comprehensive dike reinforcement measures upstream – that otherwise would have become necessary – could be avoided.

According to the Dike Act, salt marshes are an important coastal defense factor in Niedersachsen. Aiming at integrated management of the salt marshes, a pilot salt marsh management plan for the Norden region (NW Niedersachsen) was implemented in spring 2003. The plan was discussed in a working group consisting of coastal defense and nature protection agencies, dike boards and NGOs. It defines common goals and management measures of coastal defense and nature conservation for a period of 10 years (NLWK, 2003).

On the island of Langeoog, a relocation of a summer dike, which is not part of the coastal defense system, as a compensation measure for the EUROPIPE I and II pipelines, started in 2002. In all, 2.1 km^2 of summer polder area will be exposed to tidal dynamics (NLWK/BRWE, 2001).

The sandy coast

The western parts of the barrier islands are protected against erosion and storm surges by groyne-revetment systems. On Norderney and Baltrum this system has partly been reinforced and heightened. At Norderney, the 10th beach nourishment (250,000 m^3) was carried out in 2000. On Juist and Langeoog, rear side dune reinforcements became necessary to guarantee safety of the dunes against breaching under storm surge conditions (Thorenz, 2001). Sand trapping measures are carried out on a regular basis to build up the seaward side of eroded dunes. In addition, dunes are fixed by planting blow outs with marram grass or setting up sand traps where this is necessary to maintain their coastal defense function. The eastern parts of the islands consist of beach plains, dunes and salt marshes. Here, no coastal protection works are carried out and natural dynamics are allowed.

2.1.4 Germany: Hamburg

Hamburg is responsible for coastal defense on the island of Neuwerk. No reinforcement of the ring dike around Neuwerk is planned. Alternatives for better defenses against high storm tide water levels are again under discussion.

In 2004, up to 0.6 km^2 of the summer polder at eastern Neuwerk will be exposed to the tides. This is a legal measure of nature conservation to compensate for sand extraction from a nearby location. The sand is used for the expansion of premises of Airbus industries in Hamburg. In this context, several constructions will be built at Neuwerk, *e.g.*, a new summer dike to separate the eastern from the northern foreshore and a pumping station to improve the drainage of the island.

On the artificial dune islands of Nigehörn and Scharhörn no coastal protection works have been carried out or are planned to protect these uninhabited islands.

2.1.5 Germany: Schleswig-Holstein Dikes

In 2001, a new master plan 'Coastal Defense – integrated coastal defense management in Schleswig-Holstein' was adopted by the State Government of Schleswig-Holstein (MLR, 2001). In this plan, policies and strategies for coastal defense in the next 15 years are laid down. The plan implements the principles of integrated coastal zone management and contains visions and goals for an integrated coastal defense management. Also, on the basis of an evaluation of present safety standards, a priority list for necessary dike reinforcements is included. In the case of a sea level rise of 0.5 m until 2100, about 73 km of dikes need to be strengthened along the west coast of Schleswig-Holstein in the coming 15 years (MLR, 2001).

Also in Schleswig-Holstein, salt marshes are regarded an important additional coastal defense factor. Their protection and maintenance is prescribed in the Schleswig-Holstein State Water Act (version 2004). In 1995, a working group of coastal defense and environmental authorities together with the Board of the Coastal Marshes ('Marschenverband') established an integrated concept for the management of the salt marshes in Schleswig-Holstein. To monitor the results, an Integrated Salt Marsh Board (ISMB), consisting of all stakeholders and the public administration, was established. In 2000, a first evaluation showed that, in general, the salt marshes are stable or growing (horizontally as well as vertically). As a planning instrument, all members of the ISBM agree that the concept is straightforward, practically oriented, pertinent and integrative. Finally, the ISMB as an instrument of information, communication, integration and co-ordination is valued by all members. It should be stressed, however, that a board cannot provide an ultimate solution to every problem. Varying opinions and demands remain as a consequence of the different backgrounds of the members. Hence, the ISMB may be seen as a win-win approach, not a win-win solution (Hofstede, 2003).

The sandy coast

Significant erosion occurs on the west coast of Sylt and the south coast of Föhr. To balance this erosion, between 1984 and 2003 about 30 million m^3 of sand was nourished at Sylt, and 1.7 million m^3 at Föhr. Comprehensive investigations into alternative techniques to stabilize eroding sandy coasts (*e.g.*, beach drainage, artificial reefs) resulted in the acknowledgement of sand nourishment as being the most cost-effective and environmentally friendly solution (MLR, 2001).

2.1.6 Denmark

Dikes

The Danish mainland bordering the Wadden Sea is protected against flooding by 65 km of sea dike and 6 km of summer dike. A reinforcement project for the Rejsby Dike and part of the Ballum Dike is planned to be carried out in 2004-2007. The inhabited areas on the three barrier islands Mandø, Rømø and Fanø are protected by 28 km of sea defense.

Salt marsh areas in front of the dikes are created or maintained for coastal protection purposes. It is aimed at to maintain a 250-300 m wide salt marsh area in front of the dikes. The establishment of the salt marshes will continue at the same pace as in 1999. Information on drainage of the salt marshes is presented in Chapter 7.

The sandy coast

On the Skallingen peninsula dunes represent the most important form of defense against flooding. In the northern part, groynes combined with sand nourishment protect against natural beach erosion. Sand nourishment is carried out every 5 years, the last time, in 2000, this comprised about 120,500 m^3 of sand. For the southern part of Skallingen considerations regarding the necessity of coastal protection measures are still ongoing.

Up to now, sand suppletion measures have not been necessary at Skallingen, nor at the barrier islands. This is primarily due to the fact that the Danish Wadden Sea coastal area is a net sedimentation area.

2.1.7 Concluding remarks

Since the 1999 QSR considerable progress has been made on the trilateral level on the way to harmonize the interests of nature protection and coastal defense as it has been agreed in the trilateral Wadden Sea Plan (WSP §§ 3.1.6, 5.1.2). One example is the foundation of the expert group on Coastal Protection and Sea Level Rise (CPSL) in

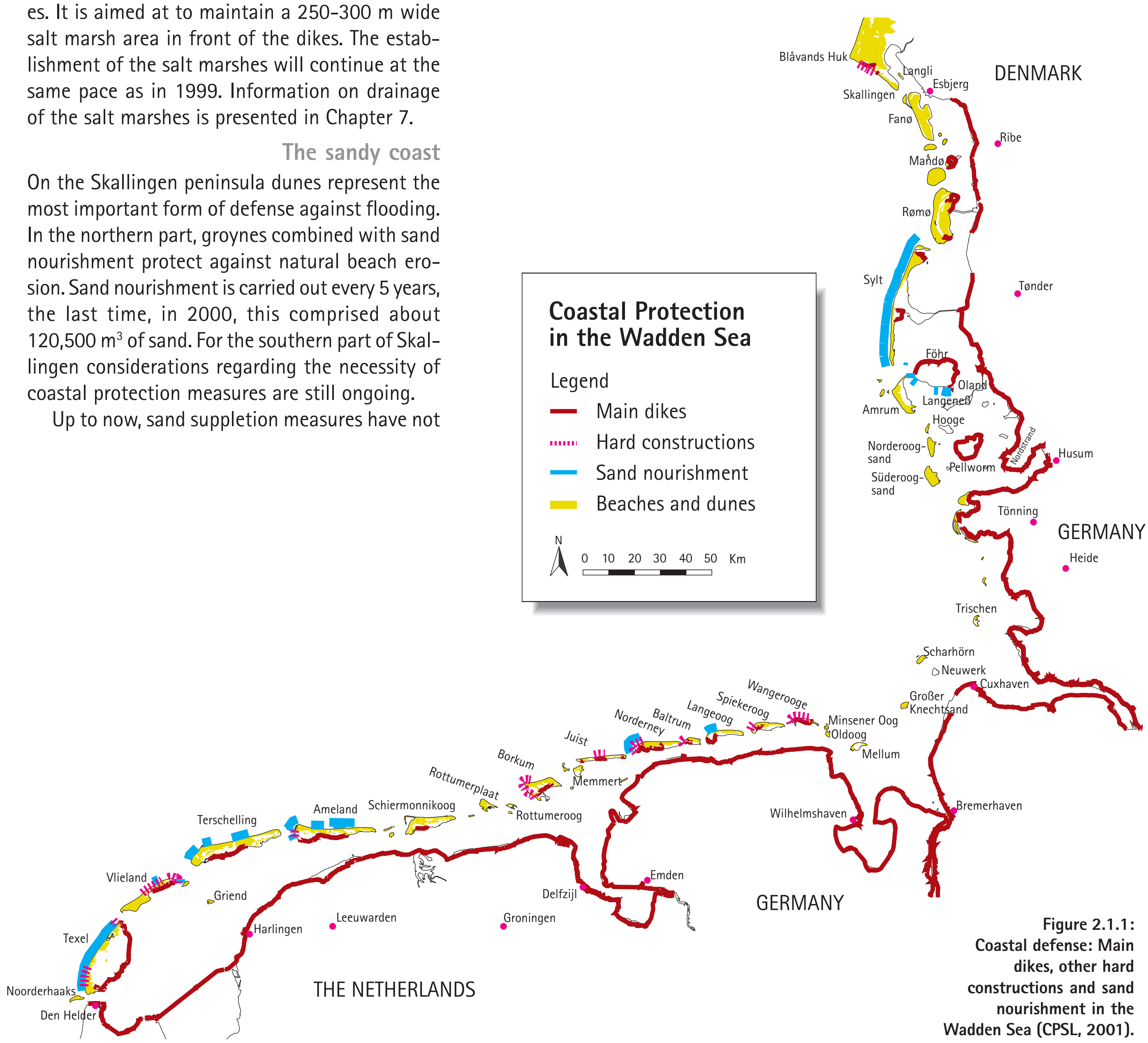

Figure 2.1.1: Coastal defense: Main dikes, other hard constructions and sand nourishment in the Wadden Sea (CPSL, 2001).

1999. For the first time, experts from national coastal defense and environmental administrations are discussing, on a trilateral level, strategies to maintain safety standards in coastal defense in a sustainable way that should be beneficial or, at least, not negative, for natural assets such as natural dynamics and habitat quality.

In addition, an integration of nature protection and coastal defense has been achieved in Germany during the last years. Examples are the positive experiences from the first five years of an integrated salt marsh management in Schleswig-Holstein and the salt marsh plan set up in Niedersachsen in 2003.

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2.2 Civil Air Traffic

Harald Marencic

2.2.1 Introduction

The number of registered take-offs and landings results from the civil airports of the Wadden Sea region, *i.e.* the airports on the islands and the adjacent mainland municipalities. Others, such as Eelde, which may also be relevant for the Wadden Sea Area but which are situated outside the defined region, have not been included. Nor are military airports included in the figures, even though some such as Den Helder, have an impact comparable to the civil airports.

In the 1999 QSR, there were no major changes observed when comparing data from 1986 and 1996 for the German and Danish Wadden Sea region, whereas in the Dutch region, an increase was observed between these years.

2.2.2 Take-offs and landings

In 2001, the total number of take-offs and landings on airfields in the whole Wadden Sea region has decreased by about 26 % compared to 1996 (see Table 2.2.1).

The relatively high number of movements in the German Wadden Sea region compared to the Danish and the Dutch region is due to the relatively larger number of airports. All islands in the Niedersachsen Wadden Sea Area (except Spiekeroog) and two in the Schleswig-Holstein Wadden Sea Area have civil airports. There is a tradition of transportation to the islands by air from larger urban centers to these islands.

In total 35 % of all the flights to the two Dutch airports in 2002 (Ameland 47%, Texel, 35%) were overland flights crossing the Wadden Sea (Jaarboek, 2002). The statistics for the German and the Danish part do not allow a more precise statement on this matter, but it should be noted that the movements on the islands of the German Wadden Sea Area are mainly airline flights and hence also overland flights.

Helicopter flights are mainly for transport to offshore installations. The main airports for helicopters in the area are Den Helder and Eelde in The Netherlands, Wilhelmshaven in Germany and Esbjerg in Denmark.

In 1993, the number of helicopter flights to offshore installations in the Dutch Wadden Sea from the two airports in The Netherlands was 266, which is a decrease in comparison to 1988 in which about 400 flights were recorded. In 1996,

	1986	1990	1996	2001	Changes 96 - 01	Changes in % 96 - 01
Netherlands						
Ameland	2,571		5,590	5,968	378	6.8
Texel	21,977		29,440	19,467	-9,973	-33.9
Total NL islands	**24,548**	**28,000**	**35,030**	**25,435**	**-9,595**	**-27.4**
Germany						
Niedersachsen:						
Borkum	20,236	20,338	15,746	15,420	-326	-2.1
Juist	38,074	37,552	33,582	16,762	-16,820	-50.1
Norderney	17,470	18,230	14,496	10,888	-3,608	-24.9
Baltrum	2,424	2,454	3,898	2,120	-1,778	-45.6
Langeoog	5,490	7,156	5,714	5,560	-154	-2.7
Wangerooge	20,226	22,936	21,823	18,980	-2,843	-13.0
Total Nds. islands	**103,920**	**108,666**	**95,259**	**69,730**	**-25,529**	**-26.8**
Emden	15,714	14,846	10,916	8,566	-2,350	-21.5
Leer-Nüttermoor	10,570	16,290	12,872	9,578	-3,294	-25.6
Norden-Norddeich	12,906	14,084	14,318	11,440	-2,878	-20.1
Harle	11,214	14,036	15,756	14,350	-1,406	-8.9
Mariensiel	20,674	24,018	30,682	21,306	-9,376	-30.6
Bremerhaven	16,902	17,562	19,388	14,540	-4,848	-25.0
Total Nds. mainland	**87,980**	**100,836**	**103,932**	**79,780**	**-24,152**	**-23.2**
Schleswig-Holstein:						
Westerland/Sylt	28,494	24,370	16,616	14,314	-2,302	-13.9
Wyk/Föhr	13,436	21,026	8,136	6,778	-1,358	-16.7
Heide-Büsum	11,630	13,124	11,234	10,292	-942	-8.4
St. Michaelisdonn	15,230	15,614	17,806	4,250	-13,556	-76.1
St. Peter Ording	16,338	4,080	6,842	2,622	-4,220	-61.7
Bordelum	1,032	1,554	1,402	272	-1,130	-80.6
Total SH	**86,160**	**79,768**	**62,036**	**38,528**	**-23,508**	**-37.9**
Denmark						
Esbjerg	24,613	27,677	18,516	18,418	-98	-0.5
Tønder	6,450	11,000	6,150	5,076	-1,074	-17.5
Total DK	**31,063**	**38,677**	**24,666**	**23,494**	**-1,172**	**-4.8**
TOTAL	**437,591**	**464,613**	**416,182**	**306,697**	**-109,485**	**-26.3%**

Table 2.2.1: Number of Landings and Take-offs of aircraft in the Wadden Sea region 1986–2001. (Note: Data of FRG flights in 2002–2004 is not completely available (only partly, only commercial flights), therefore the table refers only to the time period up to 2001). Source FRG: QSR 1999 (1986, 1996), Planco report (1990, 2001): Statistisches Bundesamt, IHK Ostfriesland (1990, since 1996 only commercial flights), Source NL: Jaarboek Waddenzee 2002 (2001, 2002), QSR 1999 (1986, 1996), Airport Den Helder, Ameland (2003,2004), Source DK: QSR 1999 (1986, 1996), Ribe Amt (2001 - 2003).

Trilateral policy and management

The impact of civil air traffic in the Wadden Sea Area will be limited. (WSP § 9.1.14)

New civil airports will not be constructed in the Wadden Sea Area. (WSP § 9.1.15)

The expansion of existing civil airports in the Wadden Sea Area is restricted to cases where this is essential in order to increase the safety of air traffic. (WSP § 9.1.16)

A minimum flight altitude of civil air traffic of 1,500 to 2,000 feet (450 - 600 m) is established in the Wadden Sea Area. Exemptions can be granted for safety reasons and will be confined to designated flight corridors situated in less vulnerable parts of the Wadden Sea Area. (WSP § 9.1.17)

The use of ultra-light aircraft will be prohibited in the Wadden Sea Area pending national legislation, with the exception of scientific and enforcement purposes. (WSP § 9.1.18)

Advertisement flights are, in principle, prohibited in the Wadden Sea Area. (WSP § 9.1.19)

Helicopter flight routes and altitudes are established in such a way that the disturbance to wildlife is minimized in the Wadden Sea Area. (WSP § 9.1.20)

(Trilateral Wadden Sea Plan (WSP), 1997)

there were 14,000 helicopter flights from Den Helder to North Sea offshore installations. In 2003, the airport received permission from the Ministry of Defense to extend the number of flight movements for helicopter from 16,000 flights to 20,000 a year (Airport Den Helder).

2.2.3 National developments

In Denmark, an executive order is in preparation to implement the agreements on flight altitudes. Negotiations have started with the National Agency for Air Traffic with a view to amending the Order on the passage over particularly sensitive nature areas by aircraft to the effect that a minimum flight altitude for civil air traffic in the Wadden Sea Area will be introduced.

In Germany, the minimum flight altitude has been 600 meters for overland flights since the 9th Order on the amendment of the Air Traffic Order was enacted in 1995.

In Schleswig-Holstein, public information and voluntary cooperation with pilots and airport administrations has increased the acceptance for nature conservation. Negotiations started in 2000 to reach additional voluntary agreements.

In The Netherlands, a minimum flight altitude for civil air traffic of 450 m is enforced over the Conservation Areas with the exemption that in specific circumstances (bad weather conditions) corridors from the airports Texel and Ameland to the mainland with a minimum flight altitude of 300 m may be used. Above the islands and the adjacent 3-mile zone, the minimum flight altitude is 150 m.

Additionally, specific flight routes (corridors) were established and the noise level of civil air traffic near airports is being monitored.

In the Netherlands, the use of ultra-light aircraft above the Conservation Area is prohibited. In the Wadden Sea Area outside the Conservation Area, ultra-light aircraft have to keep a distance of 1.5 km from 'silence areas' or environmental protection areas. At the smaller airports of Ameland and Texel the use of these aircraft is forbidden. In Germany, the relevant national regulations do not allow a prohibition of ultra-light aircraft in the Wadden Sea Area. Flights of ultra-light aircraft are an absolute exception in the Wadden Sea Area.

Helicopter flight routes have not been established in all three countries. The stipulation of the National Agency for Air Traffic encompasses guidelines for helicopter flights in the Danish Wadden Sea Area.

In Germany, the minimum flight altitude of 450 m for civil air traffic also applies for helicopters.

In The Netherlands, for civil helicopter flights above the Wadden Sea Area, a minimum flight altitude of 450 m was established in 1999 with the exemption for the use of corridors in specific circumstances from the airports Texel and Ameland to the mainland where the minimum flight altitude is 150 m.

Advertisement flights are conducted to a limited extent along the beaches in the Danish Wadden Sea Area. In Germany, advertisement flights are subject to major restrictions including their compatibility with environmental conservation. In The Netherlands, advertisement flights are forbidden in the Wadden Sea area with the exception of advertisement flights from Texel directly to the mainland. There are currently no plans for the construction of new airports or the reconstruction or expansion of existing ones in the Wadden Sea Area.

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2.3 Harbors and Shipping

Bettina Reineking

Container vessel
(Photo: K.E. Heers)

2.3.1 Introduction

Directly adjacent to the Wadden Sea Area, there are several major seaports of international significance which have considerable economic importance fort the entire region. Within the Wadden Sea Area, a number of small ports with ferry and supply traffic are relevant to tourism, the supply of islands and the mainland as well as maritime installations. The economic importance of the ports is demonstrated by a high shipping volume.

Access to the ports in connection with transit traffic to Scandinavia or to the Baltic Sea has turned the sea area off The Netherlands, the Danish and German coast into a region with the highest traffic concentrations in the world. The traffic takes place mainly in the vicinity of or – to a lesser extent – within the Wadden Sea Area

In this section, ships' traffic density, discharge regulations, and ports in the Wadden Sea Region including trends and developments are described on the basis of a study by Prognos (2004).

Trilateral policy and management

The extension, or major modification, of existing harbor and industrial facilities and new construction shall be carried out in such a way that the environmental impact is kept to a minimum and permanent, or long lasting, effects are avoided and, if this is not possible, compensated.

In the Conservation Area, new, not yet approved plans for new construction, as well as for the extension or major modification of existing harbor and industrial facilities, are not allowed unless such is necessary for imperative reasons of overriding public interest and if no alternative can be found. (WSP § 4.1.5)

With the aim of eliminating operational pollution and minimizing accidental pollution, an information and guiding system for ships carrying hazardous substances will be established. (WSP § 2.1.3)

Harbors bordering the Wadden Sea will have adequate facilities to handle all types of residues and wastes generated by ships to meet the requirements of the MARPOL Convention. (WSP § 2.1.4)

To prevent spills of oil and hazardous substances to the aquatic environment and wildlife, activities aiming at improving enforcement (surveillance and prosecution) of agreed regulations and policies to combat illegal discharges will be continued. (WSP § 2.1.5.)

(Trilateral Wadden Sea Plan (WSP), 1997)

2.3.2 Traffic density

Due to the established traffic separation schemes offshore, the sea traffic is divided according to the main traffic directions into two one-way routes. Vessels carrying dangerous goods and deep draught vessels navigate the offshore routes far away from the coast and are thus separated from the other traffic according to the International Maritime Organization (IMO) adopted mandatory routeing system. With the exception of recreational traffic, which is usually limited to the summer months, the volume of shipping is spread evenly over all the months of the year.

In view of the vessel traffic characteristics of the area, the Wadden Sea and adjacent North Sea still have an excellent record of only a few accidents and incidents. For example, during the period 1995-1999, a total of almost 800,000 ship movements in the German North Sea resulted in just over 100 incidents, some of which resulted in

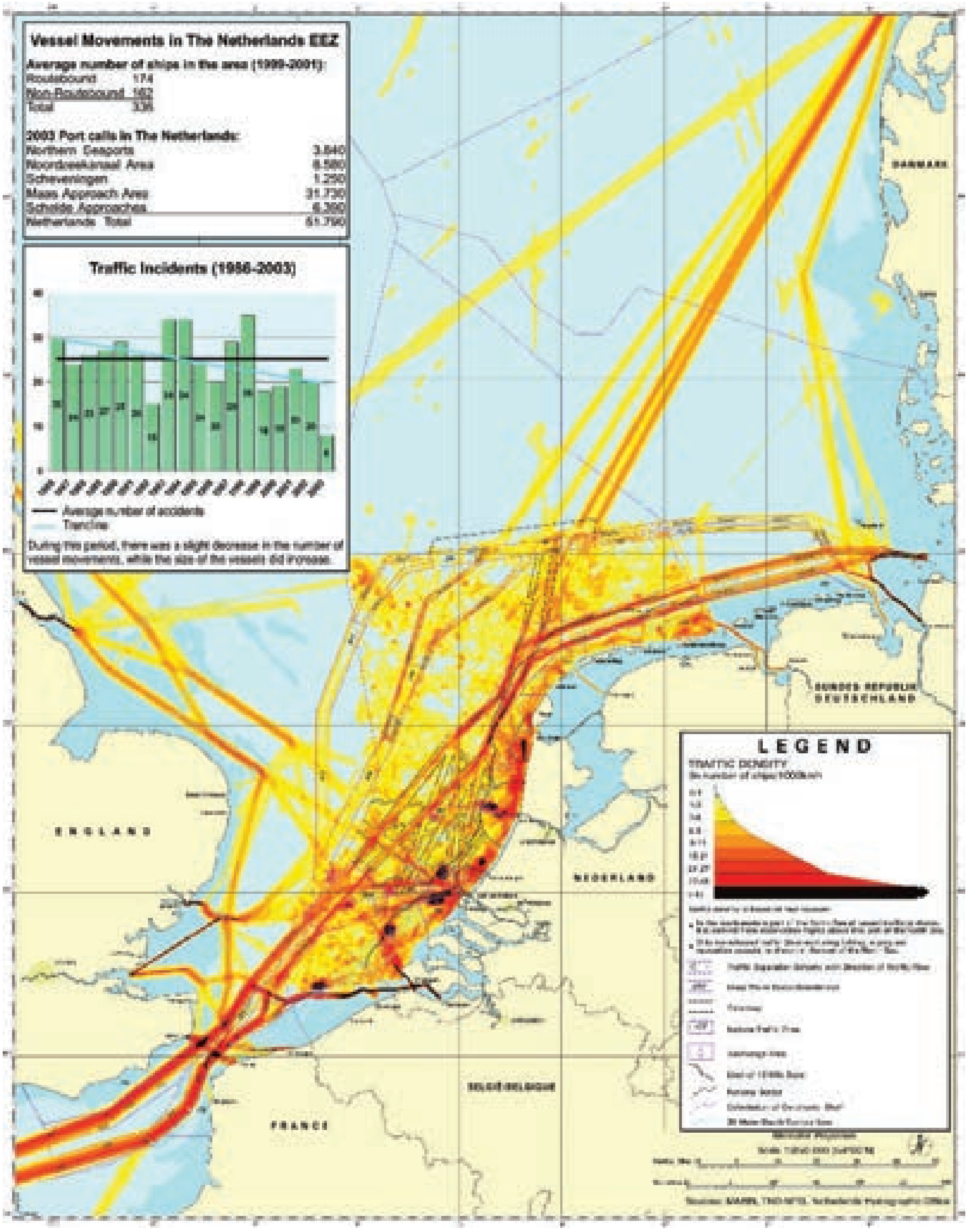

Figure 2.3.1: Vessel traffic in the North Sea. Source: Ministry of Transport, Public Works and Water Management, The Netherlands.

emergency tug deployment. Nevertheless, accidents do happen in the Wadden Sea Area, such as the 'Pallas' accident off the Danish and German coast in 1998.

Despite the existence of an extensive protective regime there is still evidence that oil and chemicals are washed ashore, containers are lost overboard, and that bilge oil and cargo residues are illegally discharged. Operational discharges are possibly more significant regarding frequency than accidental pollution, but they are difficult to quantify.

2.3.3 Illegal discharges and port reception facilities

Discharges of waste and cargo from ships at sea still occur (see also chapter 4.4 Oil Pollution and Sea Birds). The main part of the discharges are illegal, that is, in contravention of the internationally accepted rules on ships' discharges as laid down in the MARPOL 73/78 Convention.

The aim of the EC Directive 2000/59/EC on Port Reception Facilities for ship generated waste and cargo residues is to reduce the incentive to dis-

	Turnover of goods total in million tons			Difference 1992/02	Share of cargo (goods in %)			Specialization Categories of cargo
	1992	2000	2002	[%]	Container	Break bulk	Bulk cargo	
Hamburg	64.8	76.9	86.7	33.8	44	14	42	Containers, food, ore, coal, chemical
Bremerhaven	16.0	30.3	33.4	108.8	73	26	1	Containers, cars, food/fish, steel
Wilhelmshaven	31.6	43.4	38.8	22.8	1	1	98	Oil, coal, chemical
Brunsbüttel	7.9	7.7	7.6	-3.8	0	0	100	Oil
Brake	4.7	5.5	5.0	6.4	1	31	62	Corn, feeding stuff, timber
Emden	1.8	3.4	3.4	88.9	0	60	36	Cars, timber, ore
Cuxhaven	1.3	1.4	1.2	-4.9	11	60	28	Ro-ro, cars, steel, fish
Esbjerg (DK) *	4.5*	4.1	4.4	-3.1	39	6	40	Containers, fish
Delfzijl/Eemshaven (NL) **	3.3**	3.4	3.4	1.8	1	25	74	Coal, salts, food
Harlingen (NL)**	0.6**	1.0	1.1	79.7	-	-	92	Salt, potatoes, sand, gravel
Den Helder (NL)**	0.1**	0.1	0.2	41.6	-	-	-	Navy, off-shore oil industry
Total Wadden Sea Ports	**137**	**177**	**185**	**35.5**	**36**	**14**	**50**	
Amsterdam (NL)	49.2	44.6	50.3	2.2	1	11	88	Ore, coal, feeding stuff, food, chemicals
Rotterdam (NL)	291.6	318.6	322.1	10.5	20	6	74	Oil, ore, coal, food, corn, containers
Antwerp (B)	103.6	130.5	131.6	27.0	30	20	50	Ore, steel, paper, containers
Zeebrugge (B)	33.4	35.4	32.9	-1.5	27	45	28	natural gas, food, cars

Table 2.3.1: Key data for ports in the Wadden Sea region and main competitive ports. Prognos AG 2004 according to Planco, Schlussbericht WSR 2003, to havenraad.nl, Zentralverband der deutschen Seehafenbetriebe e.V., Port of Esbjerg. Note: *data Esbjerg turnover of goods in 1998 (not 1992); **data Dutch ports turnover of goods in 1996 (not 1992).

charge ship-generated waste and cargo residue into the sea by means of a differentiated No-Special-Fee system (NSF). The EC Directive is the outcome of an extremely long-lasting discussion process within the member states and allows for a non-hundred-percent NSF system, but for a differentiated implementation with minimum 30% NSF and 70% SF etc.

In terms of providing appropriate reception facilities and implementing an adequate waste handling plan, the methods of implementation of the Directive within Denmark, Germany and the Netherlands as well as in the ports are very diverse.

To overcome the deficits in the implementation of the EC Directive 2000/59/EC in the Wadden Sea countries the implementation should be improved and the interpretation should be harmonized regarding principles of fees (e.g. NSF system), parameters of fee calculation, no limitation on quantities and types of waste, and the development of clear definitions for exemptions.

2.3.4 PSSA Wadden Sea

In 2002, the marine area of the Wadden Sea Conservation Area was designated as a Particularly Sensitive Sea Area (PSSA) by the IMO in 2002 (see chapter 1.2) (MEPC, 2002). The PSSA Wadden Sea is not limiting shipping in the areas or the use of the Wadden Sea ports, but it creates additional awareness for safe passages.

2.3.5 Ports in the Wadden Sea region

The ports in the Wadden Sea region specialize in different cargo groups. Large ports such as Hamburg and Bremerhaven are all-round ports with cargo capacities for all main kinds of goods. The three biggest German ports are located in or near the Wadden Sea region (Bremerhaven, Wilhelmshaven and Hamburg). In addition, there are some smaller and medium-sized ports which have specialized in certain market niches or product categories according to the economic structure of their region (*e.g.* Eemshaven and Delzijl: chemicals; Emden: automobiles; Harlingen: fish, salt, bulk goods; Esbjerg: roll-on-roll-off and fish; Brunsbüttel: crude oil).

In 2002, the eleven main ports of the Wadden Sea region had a turnover of 185 million tons. During the last ten years the volume turnover has increased by 36% (see Table 2.3.1). The Wadden Sea ports have grown faster than their key competitors such as Amsterdam, Rotterdam, and Antwerp. With the increase of world trade the turnover of goods at the Wadden Sea ports will continue to increase in the coming years. The container segment in particular will continue to grow rapidly, at an annual rate of 4% up to 2015.

The port and maritime sector has a significant economic importance for the Wadden Sea Region. About 100,000 jobs in the region depend directly on the port and shipping industry. Additionally, about 100,000 jobs in other preliminary and downstream maritime sectors could be counted as indirect jobs in the Wadden Sea Region. Approximately 5% of all jobs depend directly or indirectly on the harbor industry in the Wadden Sea region. Including Hamburg, even every twelfth job is port-based in the region.

Trends and developments of the Wadden Sea ports

Up to 2015 the growth capacities for new port enlargements in the Wadden Sea Region are limited. The main ports in the container segment, Hamburg (Altenwerder) and Bremerhaven (CT 4) will reach their limits of expansion and management. A big chance for new port development will be the Jade-Weser-Port in Wilhelmshaven. It will expand capacities for container trade in the Wadden Sea Region (first step with max. container capacity: 2.7 million TEU). Niedersachsen and Bremen will create a new container terminal with a channel depth of 18 m for new generation ships. Expert opinion calculates an employment impact of 1,900 to 3,800 direct and indirect jobs. For Eemshaven the construction of an environmentally friendly tanker dismantling scrap yard has been mentioned.

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2.4 Tourism and Recreation

Christiane Gätje
Karsten Laursen
Hugo Eekhof
Thomas Borchardt

(Photo: M. Stock)

2.4.1 Introduction

Tourism and recreational activity is a substantial part of the public experience of the Wadden Sea, and one which also makes an important contribution to the local economy. On the other hand, tourism and recreation influence the landscape as well as the flora and fauna of the area. Therefore the Wadden Sea Plan aims at a reasonable balance between tourism and recreation on the one hand and management of landscape and wildlife on the other.

This chapter describes some principal developments in tourism and recreation focusing on indicative parameters. An overview of land-based tourism indicates the general trends of Wadden Sea tourism and its economic importance. In addition, the results of two specific TMAP monitoring parameters: Boats at Sea and Guided Tours, are presented. These two parameters give an indication of the level of the recreational activity and, over years, an impression of the trend. They are also indicative of the potential or actual level of disturbance of birds and seals.

With regard to management and nature conservation, targets on ecological and cultural-historic values were adopted for the Wadden Sea Area (Trilateral Wadden Sea Plan, 1997) whereas this was not the case with regard to socio-economic targets (Gätje, 2003).

Tourism and recreation in the Wadden Sea region is highly complex and therefore difficult to monitor, describe and analyze. The 1999 QSR explained these circumstances, with a high diversity of activities related to both land and sea, the number of areas involved (islands, coastal regions, hinterland) and the limited, poor and inconsistent data available. Since the publication of the last QSR in 1999, valuable recent information on tourism and recreation in the trilateral Wadden Sea region has been collected, analyzed and evaluated within the NetForum tourism project (IRWC, 2000a; IRWC, 2000b). Within the Wadden Sea Forum, several studies have been conducted to evaluate the available socio-economic data, including the tourism sector, for the whole Wadden Sea Region (Cowi, 2004; Planco, 2003; Prognos, 2004).

2.4.2 Land-based tourism and recreation

According to IRWC (2000a), approximately 10 million tourists and 30-40 million day trippers visit the Wadden Sea region every year (the region being the Wadden Sea, the Wadden Sea islands and the adjacent mainland areas). A turnover of about 1.5 billion Euro was estimated (IRWC, 2000b) (Table 2.4.1).

A recent study published by the Wadden Sea Forum (Cowi, 2004) gives a total number of 8.5 million overnight stays in the Danish counties of Ribe and Sønderjylland in 2001, nearly twice as many as stated in IRWC (2000) (Table 2.4.1.)

For the German coast, more detailed data is available which also cover accommodation not listed in the official statistics (Table 2.4.2). Data in comparable detail is not available at present for Denmark and The Netherlands.

Recent studies in Schleswig-Holstein (SGVSH

Table 2.4.1
Tourism in the Wadden Sea region.

	IRWC (2000a,b)*	More recent data**
	Number of beds	
Denmark	70,000 units	
Germany	130,000 units	
The Netherlands	100,000 units	
Total	**300,000 units**	
	Overnight stays	**Overnight stays**
Denmark	4.7 million	10.1 million
Schleswig-Holstein	17.0 million	15.8 million
Niedersachsen	20.5 million	30.3 million
The Netherlands	11.0 million	13.3 million
Total	**53.2 million**	**69.5 million**
	Turnover (Euro)	**Turnover (Euro)**
Denmark	267 million	
Schleswig-Holstein	688 million	
Niedersachsen	?	
The Netherlands	586 million	
Estimated Total	**1.5 billion**	**2.8-5.3 billion** (own calculation, see text)

* data source and year of data collection not specified.
** data sources:
Denmark: Cowi (2004), Danish Tourist Board, Statistics Denmark, Danhostel, year of data collection: 2001;
Schleswig-Holstein: SGVSH and TVSH (2003), Statistisches Landesamt Schleswig-Holstein, year of data collection: 2002;
Niedersachsen: Niedersächsisches Landesamt für Statistik, Bezirksregierung Weser-Ems, dwif, year of data collection: unknown;
The Netherlands: Prognos (2004), official national statistics; Toerdata Noord, Report 2003; year of data collection: 2002.

and TVSH, 2003) have shown that the official tourism statistics underestimate by far the real numbers of guests, overnight stays and, subsequently, turnover. Boarding houses and pensions with less than 9 beds as well as visits to friends and relatives contribute a considerable share (53% of total) which is not included in the official data collections (Table 2.4.2).

In the Niedersachsen Wadden Sea region, a turnover of 1.53 billion Euro for tourism (all kinds of accommodation) was calculated, based on 27.7 million overnight stays (Table 2.4.2) plus 2.6 million overnight stays on camping sites and 16.5 million day trips (Bezirksregierung Weser-Ems, 2004).

Thus, as shown in Table 2.4.2, tourism figures are substantially higher than indicated in official statistics (accommodation facilities with more than 8 beds). Table 2.4.2 gives a sum of 43.5 million overnight stays for the Niedersachsen and Schleswig-Holstein Wadden Sea region. In contrast, the inventory prepared by Planco (2003) showed only 25.5 million overnight stays for the entire German Wadden Sea region - a figure which must to be considered as a severe underestimation (Gätje, 2000a).

The daily expenditures of a tourist in Germany have recently been calculated by *dwif* (Harrer and Scherr, 2002) at 76,60 Euro (weighted average accounting for different types of accommodation). Another investigation of *dwif* in the Weser-Ems region has calculated the daily expenditures on average to be 40-46 Euro per day (RIS, 2004) Assuming that the figures indicated are plausible, a calculation of the total turnover is possible when applying them to the overnight stays in the entire Wadden Sea region using the recently available figures quoted above (total of 69.5 million overnight stays, Table 2.4.1). This gives a turnover estimate of about 2.8 to 5.3 billion Euro.

These considerations may prove that a reliable, sound and comprehensive evaluation of the available data on overnight stays and economic turnover for the whole Wadden Sea region is still not possible. The reason is that the data pool suffers from poor and incomparable data. This has already been stressed in the last QSR (de Jong *et al.*, 1999).

Table 2.4.2:
Tourism in the Niedersachsen and Schleswig-Holstein Wadden Sea regions in different types of accommodation.

Destination	North Sea Coast Niedersachsen		North Sea Coast Schleswig-Holstein	
Type of accommodation	Overnight stays	Share of total	Overnight stays	Share of total
Accommodation facilities >8 beds (recorded in official statistics)	11.9 million	43%	7.5 million	47%
Accommodation facilities <9 beds (boarding houses, pensions)	13.3 million	48%	7.1 million	45%
Visits to friends and relatives	2.5 million	9%	1.2 million	8%
Total	**27.7 million**	**100%**	**15.8 million**	**100%**

Data source Niedersachsen: Accommodation facilities >8 beds: Niedersächsisches Landesamt für Statistik, other accommodations: Regionale Innovationsstrategie Weser-Ems (RIS, 2004), year of data collection: unknown.
Data source Schleswig-Holstein: Accommodation facilities >8 beds: Statistisches Landesamt Schleswig-Holstein, other accommodations: SGVSH and TVSH (2003), year of data collection: 2002

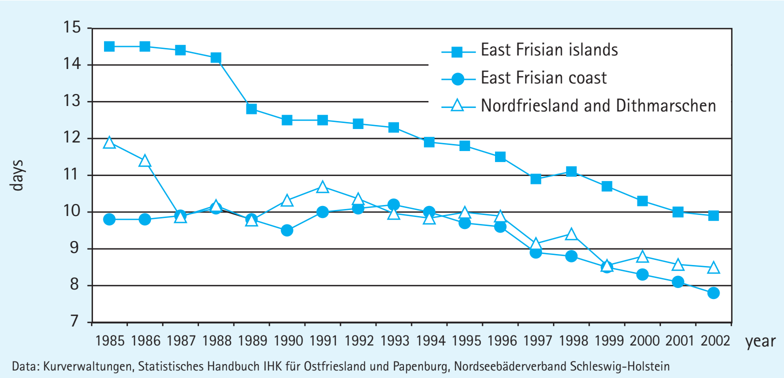


Figure 2.4.1: Average length of stay of tourists in the German Wadden Sea regions (Niedersachsen and counties of Nordfriesland and Dithmarschen in Schleswig-Holstein, period 1985-2002).

In Schleswig Holstein, the Wadden Sea National Park has implemented a socio-economic monitoring (SEM) in 1999 (Gätje, 2000b). A rising need to evaluate the regional tourism development and to trace regional effects of (inter)national tourism trends has been recognized. This led to a monitoring concept which also provides data about National Park visitors and residents, their expectations, attitudes and opinions in order to obtain a better public relations work and improve the management of protected area as a whole (Gätje, 2004a; Gätje 2004b).

SEM gives, for instance, information about a trend which probably all Wadden Sea destinations have in common: the decrease in the duration of stay of holiday makers. In the Schleswig-Holstein Wadden Sea region (counties of Nordfriesland and Dithmarschen), the length of stay has more or less continuously declined from about 12 days in 1985 to less than 9 days since 1999; in Niedersachsen (East Frisian islands and coast), there has been a similar decrease (Figure 2.4.1). Economic limits are probably responsible for this fundamental change in holiday behavior (Opaschowski, 2004), and the trend of an increasing number of short trip visitors during autumn, winter and spring.

Trilateral policy and management

It is the aim to reduce disturbance caused by recreation and tourism by introducing and applying information systems and/or temporal and spatial zoning. (WSP § 3.1.12, identical with 5.1.8).

Speed limits within the tidal area have been, or will be, imposed where such is deemed necessary. (WSP § 4.1.9)

The recreational values of the Wadden Sea will be maintained and to this end,

- in the ecologically most sensitive areas, zones have been or will be established where no recreational activities, including excursion ships and recreational boating, is allowed;
- the use of jet skis, water skis and similar motorized equipment has been, or will be, prohibited, or limited, to small designated areas;
- within the Conservation Area, new marinas will be avoided and the extension of the existing marina capacity will only be allowed within the approved levels;
- wind surfing has been, or will be, limited.

(WSP § 4.1.21)

Speed limits for ships have been, or will be, imposed, if this is deemed necessary, taking into account safety, environmental and recreational factors. (WSP § 4.1.22)

The negative effects of hovercraft and hydrofoilcraft and other high-speed craft are minimized by the following strategies:

- In The Netherlands and Germany, hovercraft and hydrofoil craft are forbidden in the tidal area of the Conservation Area; new, other high speed craft are forbidden outside the designated shipping routes in the area;
- In Denmark, applications for new, high-speed craft can only be granted on the basis of an Environmental Impact Assessment and if it is not in conflict with the nature protection targets for the area.

(WSP § 4.1.23)

It is the aim to reduce disturbance caused by recreation and tourism by introducing and applying information systems and/or temporal and spatial zoning. (WSP § 4.1.24)

It is the aim to reduce disturbance caused by recreation and tourism by introducing and applying information systems and/or temporal and spatial zoning. (WSP § 5.1.8, identical with 3.1.12).

Ground water extraction will be managed in such a way that no negative effects on wet dune valleys occur. (WSP § 5.1.10)

Disturbance in significant breeding areas will be reduced and access to these areas will be made more predictable for birds, i.e. using only certain footpaths on salt marshes, beaches and dunes (information system for visitors). (WSP § 9.1.6)

Driving cars in breeding areas on beaches and in dunes is prohibited. (WSP § 9.1.8)

(Trilateral Wadden Sea Plan (WSP), 1997)

Table 2.4.3: Participants in guided tours in the Dutch Wadden Sea (source: Stuurgroep Waddenprovinicies).

	1997	1998	1999	2000	2001	2002
Type A excursions	32,071	30,598	33,999	32,430	27,227	30,253
Type B excursions	4,376	4,582	5,694	5,700	5,682	4,981
Excursions for environmental education	33,000	34,928	37,575	38,822	46,230	35,963
Total	**65,071**	**73,142**	**78,274**	**76,952**	**79,583**	**71,197**

2.4.3 Tidal flat walking

The 'Number of guided tours' is a parameter of the TMAP Common Package. Disturbances caused by human activities are difficult to measure. However, the registration and evaluation of the number of people using tidal flats for walks and other activities enables an estimate of the relative disturbance potential. Additionally, it gives information on the participation of tourists in the kind of nature activities offered by local and regional nature centers and guides. Methods for data collection differ between the Wadden Sea countries.

2.4.3.1 Methods

In The Netherlands, the Stuurgroep Waddenprovincies collects data and publishes it regularly in the 'Jaarboek Waddenzee'. So-called Type A excursions are offered by seven organizations for large groups (50-70 participants). Type B excursions are offered by individual guides. A maximum of 12 participants is allowed. Type C-licenses are individual hikers (no participants are allowed) and excursions.

The numbers of A and B tour participants are allocated by individual quota for the seven organizations and may not exceed a total number of 50,500.

In Niedersachsen, five aerial surveys have taken place during low water and favorable weather conditions since 2000. All persons on tidal flats and beaches between the mouths of the rivers Elbe and the river Ems are counted and their geographical position is reported on maps (Frank, 2003). The counts distinguished hikers in groups, individual hikers, hikers on the beach and persons on boats.

In Schleswig-Holstein, yearly information on the number of guided tours (flat walking) and of

Figure 2.4.2: Results of flight counts in summer in the Niedersachsen Wadden Sea in 2000-2003 (sum of 5 flights respectively).

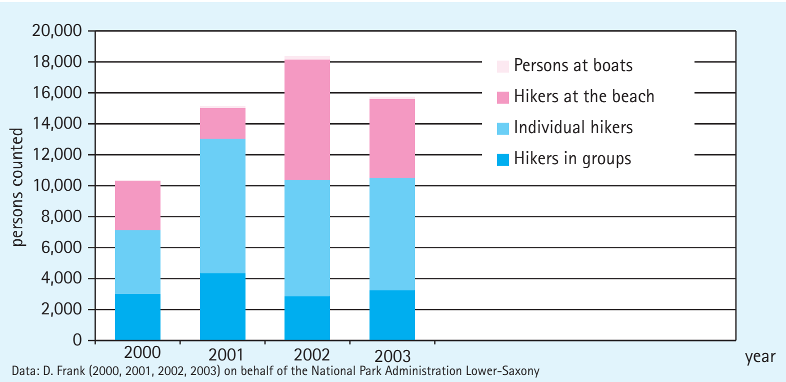
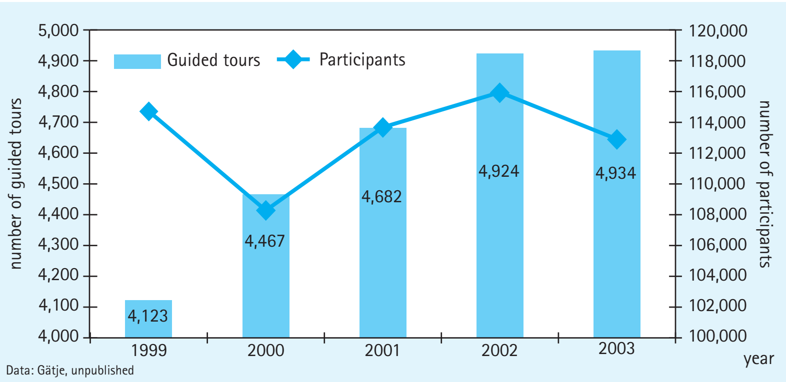


Figure 2.4.3: Number of guided tours (flat walking) and number of participants in the Schleswig-Holstein Wadden Sea region (period 1999-2002).



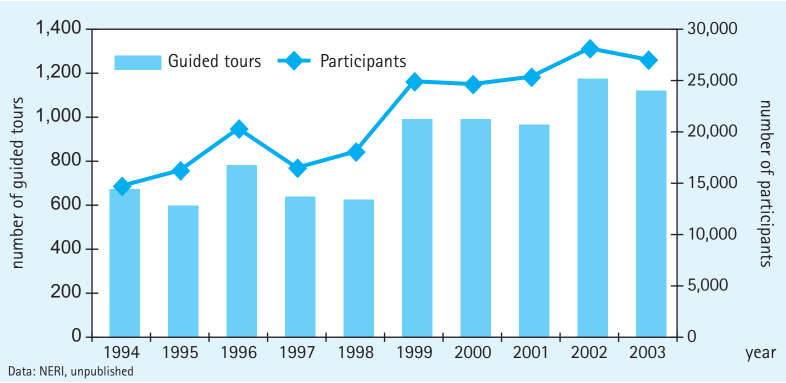


Figure 2.4.4: Number of guided tours and number of participants (period 1994–2003) in the Danish part of the Wadden Sea. Data covers flat walking, sailing trips and other kind of activities.

participants are reported on a voluntary basis to the National Park Office from guides and NGOs. An anonymous notification is also accepted. With this method, it is in fact not possible to record a hundred percent of the guided tours. However, the figures are assumed to be close to reality, since the number of unknown cases is assumed to be small.

In Denmark, the Forest and Nature Agency certifies the official guides in the Danish Wadden Sea area. These guides are mostly connected to official nature information centers and a small number act on a private basis. The nature centers and guides have been asked for information on their activities, number of events and participants since 1998. The activities are divided into three categories: tours on the tidal flats, tours on ships, and other kinds of events. This division was made to obtain an impression as to which parts of the Wadden Sea area were used for these events. Not all guides submitted their information. However, the answers probably represent the vast majority of the guided tours.

2.4.3.2 Monitoring results

In The Netherlands hiking on tidal flats predominantly takes place on the 'Groninger wad' and the eastern part of the 'Frisian wad'. The numbers of participants per year have been in the range of 65,000 to nearly 80,000 persons during the last six years (Table 2.4.3).

In Niedersachsen, the total numbers of persons counted in the Wadden Sea from aircraft varied between 10,395 in the year 2000 and 18,378 in 2002 (sum of five flights respectively) (Figure 2.4.2). Groups of hikers (assumed to be participants in a guided tour) constitute a share of 15-29% of the total number of persons recorded.

In Schleswig-Holstein the number of guided tours in the Wadden Sea increased by 20% during the period 1999-2002 (Figure 2.4.3). In 2002 nearly 5,000 guided tours with 116,000 participants took place. Of these 70% of the tours were guided by staff members of the NGOs, 22% under the direction of certified National Park guides, 6% by guides without certificate and 2% by rangers of the National Park Service (Gätje, unpublished).

In the Danish Wadden Sea area, the number of events reported rose from about 850 tours per year in 1998 to 1300 in 2003 (Fig. 2.4.4), an increase of about 57%. However, the largest increase took place from 1998 to 1999, and during the following years the numbers were rather stable. The number of participants also increased during the same period, but at a lower rate (45%). In 1998 the number of participants was 26,000 and in 2003 38,000 persons took part in the activities. Flat walking was the most popular of the three activities. In 1998, about 400 tours to the tidal flats were arranged, which increased to nearly 700 in 2003. In 1998, about 15,000 persons joined the tidal flat walking and the number increased to 21,500 participants in 2003. The number of sailing tours and the group of other activities either fluctuated or slightly increased during the same period.

General trends

For the Trilateral Wadden Sea, the results indicate that number of guided tours and number of participants have increased in Denmark and Schleswig-Holstein in recent years. The data from Niedersachsen and The Netherlands shows no clear trend.

2.4.4 Recreational boating

Several indicators are used for the magnitude and development of recreational boating: number of berths in marinas, sluice passages, and aerial counts. In The Netherlands, the harbors in the Wadden Sea region are connected to sluices. Therefore, sluice passages - which are available from official statistics - are a good indicator in this part of the Wadden Sea. In the other parts of the Wadden Sea this parameter is monitored by aerial surveys.

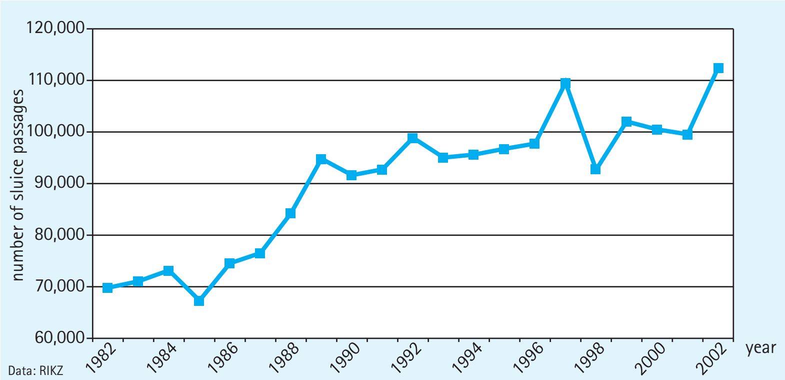


Fig. 2.4.5: Development of the number of sluice passages of recreational boats in Dutch harbors connecting to the Wadden Sea, period 1982-2002 (Den Helder, Den Oever, Kornwerderzand, Harlingen, Lauwersoog, Delfzijl).

2.4.4.1 Regulations

In the Dutch Wadden Sea there have been no changes in shipping regulations during recent years. However, some new attempts can be mentioned:

- In 2003, government and water sport organizations started a test in order to develop new regulations for falling dry. During the test period ships are allowed to fall dry in more locations in the Dutch Wadden Sea, provided that the nature is not disturbed. In the Dutch Wadden Sea, everyone has to respect the code of conduct "Wad I love you" (www.waddenzee.nl/wadikhebjelief). This code describes disturbance, places to avoid and what distance to keep from seals and birds. This trial will last four years and will be evaluated annually.
- The number of marinas in the Dutch Wadden Sea is not allowed to increase and the total number of berths in the marinas may not exceed 4,400.
- A general speed limit of 20 km/h has been introduced outside of designated shipping lanes.

In the German Wadden Sea, no changes in shipping regulations have taken place since the 1999 QSR in the three National Parks. In sensitive areas (zone 1), shipping is only allowed at high tide. At low tide, the tidal flats are used as feeding and resting places by the animals. Additionally, nearly all important moulting and feeding areas for birds and nursery places of seals are defined as seal and bird reserves. Therein shipping is prohibited in summer except along marked routes. Furthermore, speed limits have to be observed (8, 12 or 16 knot).

Due to the extension and changes in the protection zones of the German Wadden Sea National Parks in 1999 and 2001, it is intended to adapt the protection zones of the shipping regulations to the new shape of the National Parks.

In 1999, the Schleswig-Holstein National Park Office was successful in making voluntary contracts with water sport associations, aiming at the protection of moulting shell ducks. Sailors, canoeists and motorboat drivers agreed not to sail in the moulting area in front of southern Dithmarschen from 10th of July to 10th of September. Nature conservation organizations and water sport associations jointly developed a colored leaflet which shows moulting sites and routes to be avoided. Similar, but less strict voluntary agreements exist with fishermen.

In the Danish Wadden Sea, sailing including all other kinds of human traffic are forbidden close to and between the island of Langli and the peninsula of Skallingen in the northern part of the Danish Wadden Sea. Additionally, sailing is allowed in the marked sailing routes, but forbidden near high sands with roosting sites for waterbirds and haunts for seals. Windsurfing is restricted to three areas on the west coast of Rømø and Fanø respectively, and north of Esbjerg.

2.4.4.2 Methods

Development of marinas

The development of marinas in the Dutch Wadden Sea is measured every five years. The following marinas are used in the investigation (Stuurgroep Waddenprovincies, 2001): Den Helder, Den Oever, Makkum, Harlingen, Lauwersmeer area (Dokkumer Nieuwezijlen, Zoutkamp), Delfzijl, Termuntenzijl, Nieuw-Statenzijl, Noordpolderzijl and the marinas on the isles Schiermonnikoog, Ameland, Terschelling, Vlieland and Texel. In the Danish Wadden Sea, the number of boats in marinas is recorded from aircraft.

Sluice passages

The Dutch Wadden Sea can only be reached by boat through sluices, from seawards or via the German Wadden Sea. Eight places along the Dutch Wadden Sea Coastline have sluices: Den Helder, Den Oever, Kornwerderszand, Harlingen, Lauwersoog, Delfzijl, Termuntenzijl and Nieuw Statenzijl. The number of passages of the sluices of Termun-

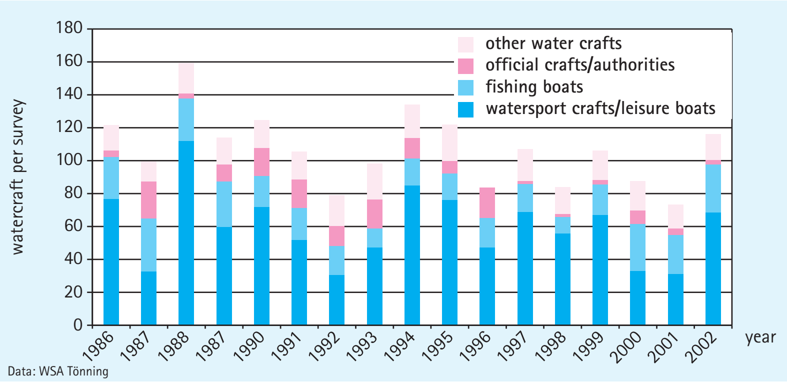


Figure 2.4.6: Average number of boats per flight in the Schleswig-Holstein Wadden Sea National Park in the period 1986-2002.

tenzijl and Nieuw Statenzijl is negligible. The number of passages is counted every year (Stuurgroep Waddenprovincies, 2001).

Aerial surveys

In the Dutch Wadden Sea, aerial surveys were performed in 1980, 1982, 1988, 1995 and 2000. From 1995, the Stuurgroep Waddenprovincies planned aerial surveys every five years. In 2000, three counts of recreational boats (sailing yachts, motor yachts, flat-bottomed boats, sport fishing boats and charter boats) were carried out in the peak season during high and low water.

In Niedersachsen, aerial surveys took place in May-August during 1988-1998, carried out by the federal shipping authorities (WSD Nordwest). All types of watercraft were registered. Because these surveys ceased in 1998 recent monitoring data is not available. Therefore, no conclusions can be drawn about the scale and trends of boat traffic in the Niedersachsen Wadden Sea.

In the Schleswig-Holstein Wadden Sea, the 'Wasser- und Schiffahrtsamt' (WSA) carried out eight aerial surveys per year in the months of June, July and August during 1986 to 2003. Number, heading and spatial distribution of boats were recorded. Additionally, boats are also counted and mapped during monitoring flights in charge of the National Park Office which are designed to record the numbers of seals or ducks visible at low tide.

In the Danish Wadden Sea, all kinds of leisure boats and ships have been recorded during aerial flights at high water by the National Environmental Research Institute (NERI). Since 1980 and up to 2000 a total 194 flights were made, during all months of the year. However since 1997 only 18 flights have taken place, mostly during autumn and winter.

2.4.4.3 Monitoring results

Sluice passages and marinas

The yearly number of sluice passages in the Dutch Wadden Sea has increased from 69,808 in 1982 to 112,432 in 2002 (the highest number since 1982). This increase occurred almost exclusively in the period 1985 to 1995 (from 69,808 to 94,823). In 1997, the highest number was reached (109,570 passages) which can probably be ascribed to favorable weather conditions. On the other hand, in 1998 the number of passages dropped to 92,679 due to bad weather conditions. During the 'normal' summers of 1999, 2000 and 2001, the number of sluice passages was about 100,000.

The number of berths in the Dutch marinas has increased from 3,411 berths in 1982 to 3,875 in 2001, which was an increase of 14% during 19 years (Stuurgroep Waddenprovincies, 2001).

During aerial surveys in the Danish Wadden Sea, leisure boats in marinas and mooring areas along

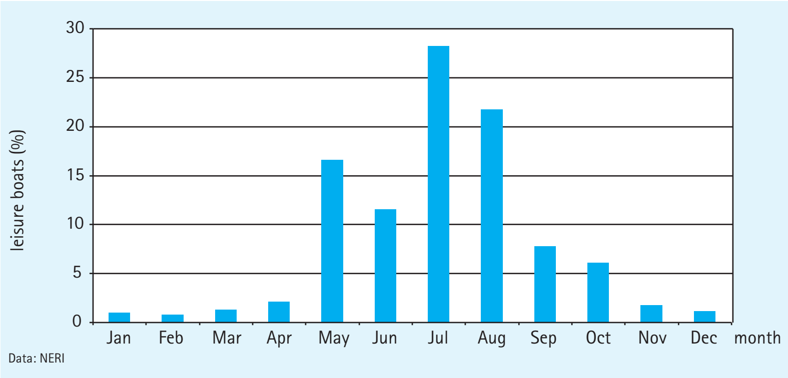


Figure 2.4.7: Monthly distribution of leisure boats (%) in the Danish Wadden Sea through a year.

the coast were recorded and the total figure was about 1,400. Most of these were counted in the marinas of Esbjerg, Nordby, Hjerting (all situated in the northern part) and Sønderho (NERI data).

Aerial surveys

In the Dutch Wadden Sea, aerial surveys revealed that the western part is the busiest, 69% of the boats were found there (in 1995: 78%). The proportion of boats in the Frisian Wadden Sea has been stable throughout the years (10%). 11% of the boats were found around the Engelsmanplaat. This has doubled in number since 1995. On the Groninger Wad and in the Ems-Dollard area, 10% of the boats were recorded. The number of boats in this region has increased since 1995, but it was higher in the 1980s.

In the Schleswig-Holstein Wadden Sea, the aircraft counts showed an average of 74-160 boats per survey in the period 1986 to 2002 (Figure 2.4.6). Of these 56% were recreational boats, 19% were fishing boats, boats from different authorities account for 8% and 17% were other kinds of watercraft (Diederichs and Grajetzky, 2004).

Considering the spatial distribution, by far the highest number of boats has regularly been recorded in the area between the North Frisian islands of Föhr and Amrum and the mainland, with its intensely frequented harbors of Dagebüll, Wyk and Wittdün.

Most boat excursions start from the harbor of Büsum (Dithmarschen) and the harbors located on the North-Frisian islands. In 2002, the various regional shipping companies scheduled more the 20,000 boat trips (Diederichs and Grajetzky, 2004). In comparison to 1992, the numbers have increased by more than 50%. In contrast, the harbor statistics and the aerial surveys show that the total number of arrivals and departures of all boat types as well as the number of boats per flight have not changed significantly during the last 16 years (Figure 2.4.6).

In the Danish Wadden Sea, pooled data from the period 1980-2003 gives information about the composition of types of leisure boats. Motor boats were the most common and made up 46% of all recorded leisure boats. Windsurfers were the second most common with a share of 42%. Rather few rowing and sailing boats were recorded and they accounted for only 25 and 10% respectively. In total 50% of the boats were counted in the months of July and August (Figure 2.4.7), and in this period up to 100 leisure boats were recorded per survey.

The geographical distribution of leisure boats in the Danish Wadden Sea showed that the northern part, the area off Esbjerg, is used by a vast majority of boats. The area between Ribe and the southern part of Fanø is used by a small number of leisure boats, while boats recorded in the southern part of the Danish Wadden Sea are few in number (Laursen *et al.*, 1997). Figures indicate that this distribution has not changed during the last years.

Comparison between the number of leisure boats recorded as actively sailing and the number of boats moored in harbors or along the coastline, showed that only up to 5% of the boats are recorded as in use on a given day (exclusive wind surfers) (Laursen *et al.*, 1997).

General trends

Only in the Dutch Wadden Sea can a clear trend be seen with respect to the number of boats. Both the number of sluice passages and the number of berths have increased since 1982. In Schleswig-Holstein, the boat traffic has not significantly increased or decreased during the last 20 years. The highest density of leisure boats and excursion boats/ferries was observed around the North Frisian islands. In the Danish Wadden Sea, data shows a high sailing activity in the Northern part in the Esbjerg-Fanø area. However, trends cannot be calculated.

2.4.5 Conclusions and Recommendations

Land-based tourism

Tourism has an extraordinary high economic value for the region (estimated turnover of 2.8-5.3 billion Euro) and provides an increasing number of jobs (about 37,900 jobs in the entire Wadden Sea region in 2000) (Prognos, 2004). Due to globalization, intensified competition and modified consumer habits, tourism in the Wadden Sea is subject to changes, which opens up new opportunities at the same time. The growth markets of wellness/fitness, walking/hiking, and nature-oriented holidays and leisure activities fit well into the Wadden Sea region. Also the aging population may have a positive consequence (Prognos, 2004). Therefore, attractive outdoor and indoor offers are important for nature experience, emotional experiences and fun-oriented environmental education for all target groups, disabled and elderly people included. However, the image of the Wadden Sea region and its tourist attractions could be better communicated by common promotion in Denmark, Germany and The Netherlands (Prognos, 2004).

The common package of the TMAP (Stade Declaration, 1997) comprises only a few socio-economic parameters. Up to now, a standard program is lacking, which leads to gaps in data. Where data is available, comparability is often hampered due to different methodologies (IRWC, 2000; Gätje, 2003). Therefore, the development of a (standard) tourism monitoring in the Wadden Sea region is long overdue. Some appropriate parameters and standard methods have already been proposed and discussed at the thematic TMAP expert workshops (Marencic *et al.*, 1996; Möller, 1996). The establishment of a socio-economic monitoring with trilaterally harmonized data collection in the Wadden Sea region and an implementation within the trilateral monitoring and assessment program (TMAP) will ideally allow an application of appropriate measures and actions in tourism planning, decision-making and management (IRWC, 2000; Gätje, 2003).

Tidal flat walking and recreational boating

Since the 1999 QSR an increase of tidal flat walking activities could be observed in Denmark and Schleswig-Holstein, and it can be assumed that a comparable development may have taken place in other Wadden Sea regions. For recreational boating, there has been an increase in The Netherlands since 1982, but no trends could be observed in the other regions.

It is difficult to evaluate the trend observed in the two parameters. However it seems that the figures for recreational boating are very dependent on weather conditions in a given year. While tidal flat walking probably reflects a general interest from the public in seeing and learning about the Wadden Sea, on the other hand information on organized flat walking covers only a very restricted part of the Wadden Sea area, and for a limited number of sites which are more or less the same from year to year. This is probably also true for recreational boating. For these reasons, neither parameter can therefore really be considered as an indicator for the disturbance of waterbirds or seals in the Wadden Sea. To obtain those kind of parameters, more detailed information is required, as demonstrated for the studies of potential human disturbance of waterbirds at roosting sites (Koffijberg *et al.*, 2003), and the relationship between human activities in the Wadden Sea and numbers of different waterbird species at particular counting sites (Laursen *et al.*, 1997). In the best case the two parameters can only give indicative information on the trend of human activities in the Wadden Sea. However, this requires that the methods of monitoring the parameters are harmonized for the different regions.

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2.5 Fishery

Harald Marencic

Blue mussel vessel
(Photo: C. Buschbaum)

2.5.1 Introduction

The main fisheries in the Wadden Sea are for brown shrimps and blue mussels. *Spisula* fishery (*S. solida* and *S. subtruncata*) was mentioned in the 1999 QSR as new type of shellfish fishery (started in the late 1980s), partly carried out by fishermen specializing in cockle fishery. This takes place offshore and only partly in the 3-mile zone. Aquaculture is not carried out in the Wadden Sea with the exception of one oyster culture on the island of Sylt; blue mussel culture lost can also be regarded as a form of aquaculture.

An overview of national shellfish policies in the trilateral Wadden Sea was compiled in 2002 (CWSS, 2002). The following chapters give a summary of this report together with an overview of recent developments and an update of the landings of blue mussel and cockles, as well as shrimps. In Table 2.5.1, facts and figures for shellfish fisheries in the Wadden Sea are given.

The focus of this chapter is on the Wadden Sea Area and on blue mussel, cockle and shrimp fisheries. A more detailed analysis of the fisheries' sector of the Wadden Sea region with emphasis on the economic aspects is given in the Wadden Sea Forum Report (Prognos, 2004).

An overview of fishing activities in the whole North Sea together with an assessment of fish stocks is given in the Quality Status Report by the OSPAR Commission (OSPAR, 2000) and ICES (2004).

The framework for the coastal fisheries (off the 3 sm line) is given by the Common Fishery Policy of the European Union.

2.5.2 Blue mussel fisheries

Fisheries of blue mussels have been regulated in all countries with regard to the amount of permits, size of culture lots, fishing periods and other regulations (see 2.5.2.1 and Table 2.5.1).

In The Netherlands and Germany, fisheries are mainly carried out on seed mussels from wild natural beds. The seed mussels are then dispersed on culture lots where they grow to marketable size. The total size of culture lots in the Wadden Sea is about 101 km² (see Table 2.5.1). In Denmark, commercially sized mussels are fished from wild natural beds. In Niedersachsen, fishing for consumption mussels is only allowed on sublittoral banks; only small amount have been fished (about 200 t in 2002). Blue mussel fishery is not allowed in the Hamburg National Park.

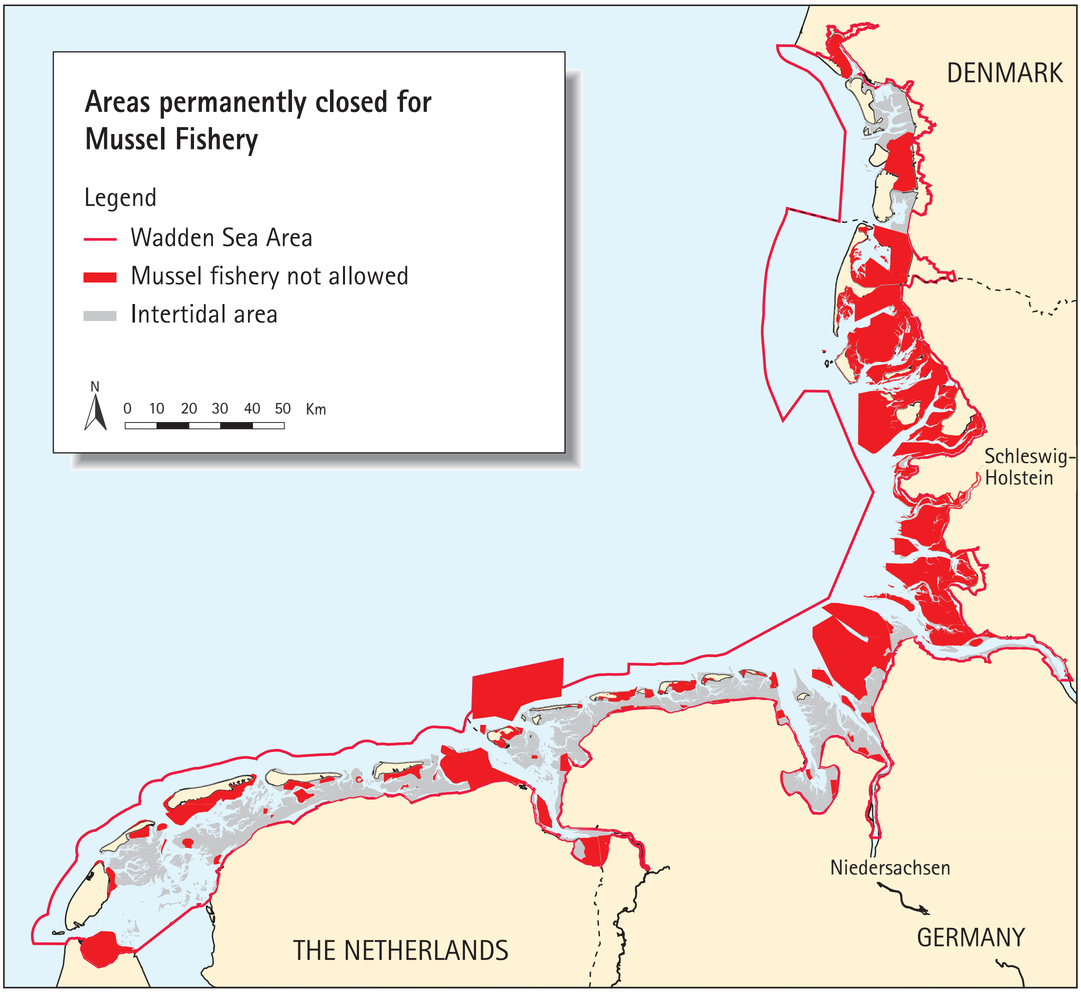
Parts of the Wadden Sea Area (intertidal and subtidal areas) are closed for blue mussel fisheries.

Blue mussel fishery is strongly dependent on natural conditions. Therefore the catches of mussels show strong fluctuations per year and region. In the last ten-year period, the years 1998 and 1999 allowed higher catches, whereas in 2001 and 2002 the lowest catches were reported.

The average annual landings of mussels in the past 10 years (1994-2003) were about 65,000 tons wet weight (including shells), most of them (about 39,000 t) were landed in The Netherlands (Figure 2.5.2).

The majority of landings are traded in The Netherlands. A considerable part of the German landings are transported to The Netherlands for processing and trading.

Figure 2.5.1: Areas in the Wadden Sea Area, permanently closed for mussel fishery in 2004.



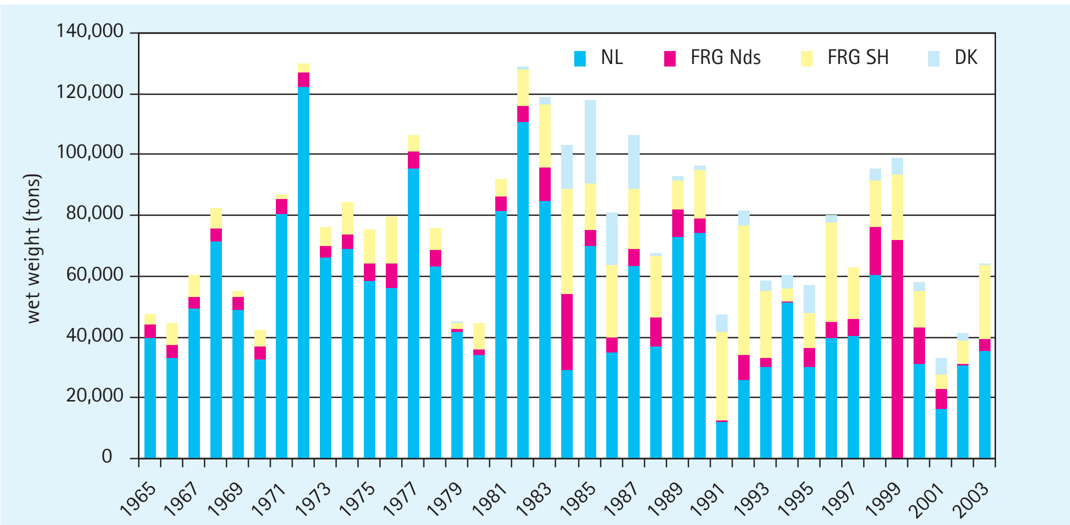
2.5.2.1 National developments

The Netherlands

Fishing for blue mussels in the Dutch Wadden Sea is only done for seed mussels. Seed mussels are spread on mussel culture lots. The area designated for culture lots is 7,200 ha of which 3,550 ha are currently in use. The culture lots are situated in the subtidal of the western part of the Dutch Wadden Sea.

The average annual landings of mussels from culture lots in the past 10 years (1994-2003) were 39,132 tons of gross weight (including shells). An

Figure 2.5.2: Landings of blue mussels in the Wadden Sea 1965–2003 (in tons wet weight) (sources: DFU, Fischerblatt, RIVO, PVIS).



overview of facts and figures is given in Table 2.5.1.

The National Planning Decree (Planologische Kernbeslissing, PKB) for the Wadden Sea sets out the general policies for all human uses in the Wadden Sea conservation area, including shellfish fisheries. In 2005, a new policy plan will be published.

With regard to shellfish fisheries, the PKB refers to the Sea and Coastal Fisheries Policy Document (Structuurnota Zee- en Kustvisserij) which was published in 1993 and has since formed the basis for fisheries policy. The policy focuses on three keystones: closed areas, food reservation for birds and co-management (CWSS, 2002).

On the basis of an interim report in 1998 and new observations in 1999 and 2000 it was decided to take additional measures in order to enhance the restoration of blue mussel beds in the Wadden Sea and to improve the food availability for birds, by additional closure of 5% of the intertidal area for cockle fishery (and 10% for mussel fishery) of areas with high potential for blue mussel beds and new measures to prevent food shortage for birds (CWSS, 2002; Ens *et al.*, 2004).

This 2nd policy phase was accompanied by a comprehensive research program (EVA II) which began in 1999 and ran until 2004 (LNV, 2003; Ens *et al.*, 2004; www.eva2.nl).

Four main policy questions were addressed concerning the effects of fishery on benthic biotopes, the effectiveness of closed areas and food reservation for birds and, the requirements with regard the EC Birds and Habitats Directive and additional policy measures to be taken to counter possible adverse effects from fishery. New insights gained with regard to the effects of shellfish fishery on benthic biotopes and food availability for eider ducks and oystercatchers as well as the functioning of the ecosystem as a whole. In 2004, the Dutch shellfish organizations published a plan for future fisheries management based on the EVA II results (ODUS, 2004).

The results of the scientific research program EVA II were used as a basis for the development of a new shellfish policy which was adopted by Parliament in October 2004 (LNV, 2004). which contains some a significant change, including the discontinuation of mechanical cockle fishery in the Wadden Sea as of 1 January 2005: The new policy holds for:

- re-opening of the '5%-areas' which were additionally closed in 1999,
- end of the food reservation policy in the Wadden Sea due to the ban of mechanical cockle fishery,
- blue mussel seed fishery in subtidal areas is only allowed on instable mussel beds in autumn,
- experimental fishery accompanied with research on unstable intertidal blue mussel beds and seed fishery on unstable beds if at least 2,000 ha of one year old mussel beds are left,
- stimulation of alternative sources for blue mussel seed (farming).

Trilateral policy and management

The negative effects of cockle fishery are being limited by:

- Cockle fishery is not allowed in the German part of the Conservation Area;
- Cockle fishery is not allowed in the Danish part of the Wadden Sea Area, with the exception of some small areas along the Esbjerg shipping lane and in the Ho Bay;
- Cockle fishery is allowed in the Dutch part of the Wadden Sea Area, but has been limited by the permanent closure of considerable areas; there are possibilities for additional restrictions to safeguard food for birds. A co-management scheme with the fishing industry is in operation, in which the protection and enhancement of the growth of wild mussel beds and *Zostera* fields are central elements.

(WSP §§ 4.1.16; 9.1.3).

The negative effects of mussel fishery are limited by the permanent closure of considerable areas. In addition, the management of fishery on mussels aims at, inter alia, protecting and enhancing the growth of wild mussel beds and Zostera fields. (WSP §§ 4.1.17; 9.1.4).

Mussel fishery will, in principle, be limited to the subtidal area. Based on national management plans, which are documented in the Progress Report, fishery on the tidal flats may be granted. The fishery sector is called upon to exchange information on the existing practices and to investigate possibilities for minimizing impacts of mussel fishery, in general and seed mussel fishery, in particular. (WSP §§ 4.1.18, 9.1.5).

The current area of mussel culture lots will not be enlarged. (WSP § 4.1.19)

The existing permit for oyster culture will remain in force for traditional reasons. According to this permit, the imported oysters originate

from hatcheries and are under veterinary control. New permits will not be granted. (WSP § 4.1.20)

Germany: Niedersachsen

In the Niedersachsen part of the Conservation Area seed mussels are fished in the subtidal and certain parts of the intertidal area. Consumption mussels may only be fished in the subtidal (in 2002 about 200 tons).

Five licenses have been issued for mussel seed fishing. There are culture lots with a total size of maximum 1,300 ha. The average annual landings of mussels (from cultures and wild mussels) over the period 1994-2003 were 7,278 metric tons gross weight. The facts and figures have been summarized in Table 2.5.1.

According to the National Park Law seed mussel fishing is allowed in a number of explicitly specified parts of zone I (the most protected zone) and the whole of zone II (intermediate protection zone). The area of zone I which permanently closed for mussel fishing has a total size of approximately 93,480 ha. The major parts are formed by one area between Weser and Elbe and the Borkum Riff ground (Figure 2.5.1) It has to be stressed that not all parts of zone 1 are suitable for mussel fishing.

Blue mussel fishery is regulated according to the Niedersachsen Fishery Ordinance of 1992 by the State Fisheries Administration. The National Park Administration is consulted in the licensing procedure.

Seed mussel fishing is only allowed within the framework of a management plan (Bewirtschaftungsplan, 2004), issued jointly by the fisheries and nature protection authorities. The management plan takes account of the protection aims as laid down in §2 of the National Park Law. The first management plan was issued for the period 1999-2003 (CWSS, 2002) and was recently amended for the period 2004-2008 based on the results of a scientific research project carried out 2000-2003 (Herlyn and Millat, 2004). The framework, main principles and measures of the previous management plan remained unchanged. According to the plan, 29 of the total of the described 102 mussel bed sites have been excluded from seed mussel fisheries: 12 sites already excluded according to the National Park Law, 12 additional sites excluded according to the management plan and five additional sites which are voluntarily excluded from fishery to enable a long-term monitoring and a reliable calculation of the total blue mussel stock.

Germany: Schleswig-Holstein

In the Schleswig-Holstein National Park, fishing for seed mussels is only allowed within the subtidal part of zone 2 and in the subtidal part of four defined areas in zone 1. Fishing for seed mussels in the intertidal of the National Park is forbidden (CWSS, 2002).

The average annual landings from culture lots in the period 1994-2003 were 15,167 metric tons gross weight. The total size of the culture lots in 2003 was 2,200 ha. The facts have been summarized in Table 2.5.1.

According to the National Park Law fishing for seed mussels is only permitted with a license according to §40 and 41 of the Schleswig-Holstein Fisheries Law. The areas where fishing is allowed have been fixed in the Schleswig-Holstein mussel fishing program, which has been issued in accordance with §40-1 of the Fisheries Law.

Since 1997 a mussel fishing program for the use of mussel resources in the National Park of Schleswig Holstein has been in force which was amended within the framework of the revision of the National Park Law in 2000. A Framework Agreement between the Ministry and the fisheries sector for the period until end of 2016 has been agreed upon. The main elements contained in the agreement are the specification of the conditions under which mussel seed fishery and mussel fishery may be carried out and the development of fishing and culture practices in the period under consideration (CWSS, 2002). A detailed overview of the recent monitoring and management is given by Nehls and Ruth (2004).

Denmark

In the Danish part of the Conservation Area fishing for wild blue mussels is allowed in three areas with a total size of 28,700 ha (42% of the Tidal Area; see Figure 2.5.1) and fishing for cockles in three small areas in the Grådyb. Mussel culture is not allowed.

The annual landings of wild blue mussels were on average 4,507 metric tons gross weight in the period 1994-2003. The minimum landing size is 50 mm in length. The data has been summarized in Table 2.5.1.

Because of overfishing and severe winters, which in the 1980s caused a decline in numbers of some waterbird species, and reduction of intertidal mussel beds, mussel fisheries in the Danish Wadden Sea have been severely restricted since the end of the 1980s. The number of licenses has been reduced from 40 to 5 and an annual quota of mussels is negotiated with the Ministry for Environment, allowing for a surplus as food for staging birds, based upon stock assessments by the Danish Fisheries Research Institute. In recent years the quota has been a maximum 10,000 tons.

In 2002, the Danish Directorate for Fisheries has given permission to a nature restoration project for blue mussel beds in parts of the Danish Wadden Sea. The project is a cooperation between the Danish Fishermen's Association and the Danish Institute for Fisheries Research, with the latter as the responsible partner. The project has the intention to restore mussel beds in 'Ribe Løb'

Table 2.5.1: Shellfish fishing. Overview of facts (modified from CWSS, 2002). Updates are given in bold.

	NL	NDS	SH	DK
Size Tidal Area (ha) according to trilateral definition (WSP)	250,000	183,400	222,000	68,500
Intertidal (ha)	124,000	144,000	141,000	55,400
% Intertidal	49.6	78.5	63.5	80.9
Average annual mussel landings (metric tons gross)	37,712 (91-2000) **39,132 (94–03)** (from culture lots)	7,332 (91-2000) **7,278 (94–03)** (culture + wild)	20,837 (91-2000) **15,167 (94–03)** (from culture lots)	4,152 (91-2000) **4,507 (94–03)** (wild mussels)
Mussel culture in use (ha)	6,500 **used**: 3,560	1,300 (maximum)	2,200	-
Number of licenses	89 (seed fishing vessels), 82 mussel culture	5 (vessels)	8	5
Quota	For seed mussels			On the basis of stock assessment. In recent years 10,000 tons
Permanently closed area (ha)	42,540 (this area covers 18% of total intertidal stock)[1)]	**93,480** (this area covers about **10** % of total area of intertidal mussel beds)[2)]	141,000 (this area covers 100% of intertidal mussel beds)	28,700
Additional restrictions	**Intertidal: Seed fishery on unstable mussel beds only if at least 2000 ha of 1-year old mussel beds are left.**	Additionally 17 sites closed in accordance with Management Plan (about **10%** of intertidal mussel beds)[2)]		Min. size consumption mussel = 5 cm
Average annual cockle landings (tons wet weight)	Mechanical: 23,215 (1991-2000) Non-mechanical: 2,333 (2000) **1994–2003: 21,056**[3)]	53 (1999)	-	7,000 gross weight = 1,118 t ww (1990-1999) **1994–2003: 969**
Number of licenses/vessels	23/37 (8-14 vessels active in Wadden Sea) [3)]	1 (1999)	-	1
Permanently closed area for cockle fishery	**100% (mechanical cockle fishery)**[3)]	100% of conservation area	100% of conservation area	99% of conservation area
Additional restrictions				Min. size 16 mm
Spisula landings annual average in tons fresh weight (period)	34,630 (1996-1999) **36,160 t (1998–2003)**	No landings since 1996	No landings since 1995	1,978 (1992-1995) 1996-1998 no landings **2,846 (1999–2003)**
Number of licenses	46 of which 8 active	None	6	5 (1 active)
Restrictions	Size >30 mm	-	Size >30 mm	
Only outside 3-mile zone	Size >35 mm			
Oyster culture	Not practiced	Not practiced	1 oyster culture lot	1 license (not used)

[1)] Based upon average annual biomass in spring 1999-2001. Permanently closed area is about 26% of the intertidal area.
[2)] Average of 5 years (1999-2003): range 9.5-13.2 %. Additionally, about 10% of the mussel bed areas (average 1999-2003) is closed for fisheries (range: 8.4-12.5%) (Herlyn and Millat, 2004). The closed area covers 33.8% of the National Park area; not all parts of the closed area are suitable for fishing.
[3)] Mechanical cockle fishery in the Dutch Wadden Sea was closed on 1 January 2005. No cockle fishery in 2004 because of a legal procedure against the licensing procedure.

and 'Jørgens Lo'. Up to 1,000 tons of blue mussel seed will be fished in 2002 in the Horns Reef area, more than 10 km west of the Wadden Sea conservation area, and be placed on the seabed in the Wadden Sea Area. The time period for the project is three years. The restored mussel beds will be monitored and fisheries will not be allowed in this period. The Danish authorities have financially supported the project.

2.5.3 Cockles

Fisheries of cockles have been regulated in all countries with regard to the amount of permits, size of culture lots, fishing periods and other regulations (Table 2.5.1).

Most parts of the Wadden Sea Area are closed for cockle fisheries; it is not allowed in the German National Parks and the Danish Wadden Sea with the exception of some small areas along the Esbjerg shipping lane and Ho Bay. In The Netherlands, mechanical cockle fishery was stopped as of 1 January 2005 (see chapter below).

The average annual cockle landings for the period 1994-2003 are about 22,000 tons (wet weight), almost all landed in The Netherlands. In 2000 to 2003, the landings were lower than in 1998 and 1999 (Figure 2.5.3).

2.5.3.1 The Netherlands

The average annual cockle landings from mechanical fishing in the Dutch Wadden Sea were 21,056 metric tons of gross weight for the period 1994-2003 (Figure 2.5.4). There is also non-mechanical fishing of cockles and the amount fished in 2000 was about 2,333 metric tons (350 tons of meat).

Management of cockle and blue mussel fishing in The Netherlands have many similarities and are therefore treated within the same common shellfish fishery policy (Sea and Coastal Fisheries Policy Document, Structuurnota Zee- en Kustvisserij) (CWSS, 2002).

A new shellfish policy was adopted in 2004 (LNV, 2004) which contains some significant changes, including the discontinuation of mechanical cockle fishery in the Wadden Sea as of 1 January 2005, re-opening of the '5%-areas' which were additionally closed in 1999, end of the food reservation policy in the Wadden Sea due to the ban on mechanical cockle fishery.

In 2004, the European Court of Justice concluded that the Dutch Government was only allowed to give permits for mechanical cockle fishery in the Wadden Sea if there was no reasonable doubt that cockle fishery had no harmful consequences for the ecosystem according to the EC Habitats Directive. Accordingly, the Dutch Administrative Court had to consider the case of mechanical cockle fishery again and no cockle fishery was carried out in 2004.

An overview of facts and figures is shown in Table 2.5.1.

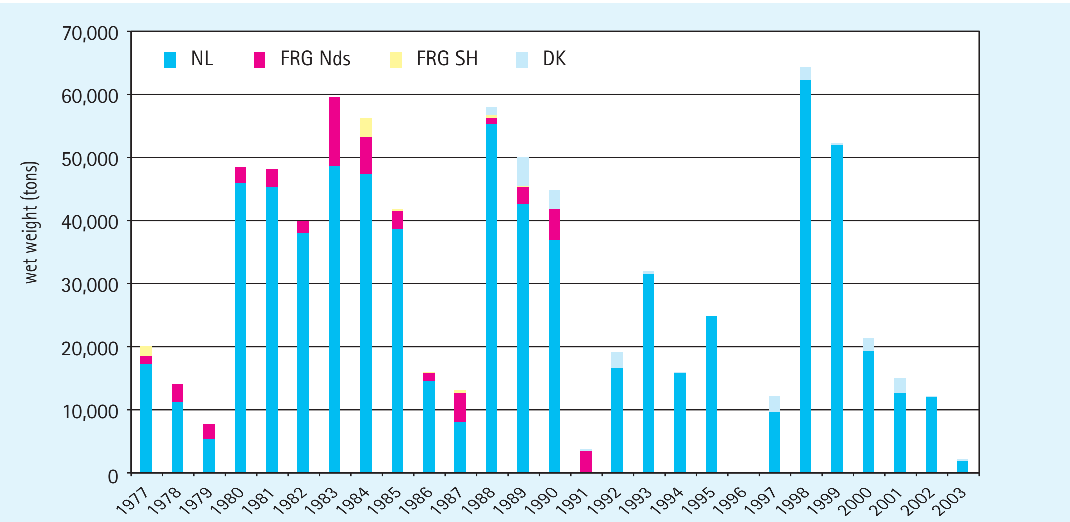
2.5.3.2 Germany

Cockle fishery in the Schleswig-Holstein was stopped in 1989 and in the Niedersachsen National Park in 1992 and is not allowed in the Hamburg National Park.

2.5.3.3 Denmark

There is one license for cockle fishing. Cockle fishing is restricted to three small areas in the Grådyb, of which one may be fished per year. Of the four areas, only two are currently suitable for fishing. Recent applications for a license for fishing cockles in another area and for trading for another area were rejected.

Figure 2.5.3: Landings of cockles in the Wadden Sea 1977-2003 (in tons wet weight) (sources: DFU, Fischerblatt, RIVO, PVIS).



In the period 1994-2003 an average annual amount of about 969 tons wet weight of cockles was fished (Figure 2.5.4).

2.5.4. Other Shellfish Fisheries

2.5.4.1 The Netherlands

In recent years fishing for *Spisula subtruncata* has been carried out in the offshore area. The average annual landings in the period 1996-2003 were about 36,160 tons of fresh weight (about 3,600 t meat).

Currently, a comprehensive policy for the fishery of *Spisula* (and other shellfish species) is under preparation. It is expected that decisions about the new policy will be taken in of 2005.

2.5.4.2 Germany

In Niedersachsen, there has not been any fishing of *Spisula* species or other shellfish species in the Wadden Sea Area since 1995.

In Schleswig-Holstein, fishing of razor clam (*Ensis* spp.) is not allowed in the Conservation Area. *Spisula solida* fishing may only be carried out outside the 3-mile zone. Since 1996, there has not been any *Spisula* fishing. There is one license for oyster (*Crassostrea gigas*) culture in Schleswig-Holstein. The culture area has a size of 30 ha.

In the Hamburg National Park, shellfish fishing is forbidden in the whole area.

2.5.4.3 Denmark

In Denmark, about five licenses have been issued for *Spisula* fishing, but only one vessel has been fishing in two offshore areas. The minimum landing size is 13 mm in width and about 35 mm in length. The total Danish reported landings were 7,885 t over the years 1992 to 1995. In 1996, the whole *S. solida* stock in the two fishing areas disappeared, probably because of the cold winter of 1995/96. In 1999, Spisula fishing started again with an annual average of 2,846 t/yr (1999-2003).

There is one license for oyster culture in Denmark which is currently not in use.

2.5.5 Shrimp Fishery

In all three Wadden Sea countries, the main fishery activities for brown shrimp *(Crangon crangon)* are carried out outside the Wadden Sea on the North Sea side of the islands, where fishing is also possible during winter. The Wadden Sea Conservation Area closed to shrimp fishery only in 95% of the area of the Hamburg National Park in Germany. Generally, there are no substantial differences in policies and practices within the Trilateral Cooperation Area.

The total number of vessels involved in shrimp fishing is about 500 (about 240 in Germany, 25 in Denmark and 230 in The Netherlands) (Breckling, pers. comm). The data about landings, recorded in each country, does not differentiate between the yield fished in or outside the Wadden Sea Area. The yearly average catch in the total landings of shrimp for the period 1994-2003 was about 25,000 t (Figure 2.5.4).

2.5.5.1 The Netherlands

In The Netherlands, shrimp fishery is carried out by 230 licensed vessels (of which 90 vessels are operating in the Wadden Sea). The total average annual catch in The Netherlands (including that from vessels outside the Wadden Sea) was about 10,000 t in the time period of 1994-2003.

2.5.5.2 Germany

In the German part, the shrimp catch has been on average around 11,000 t/yr. In Schleswig-Holstein,

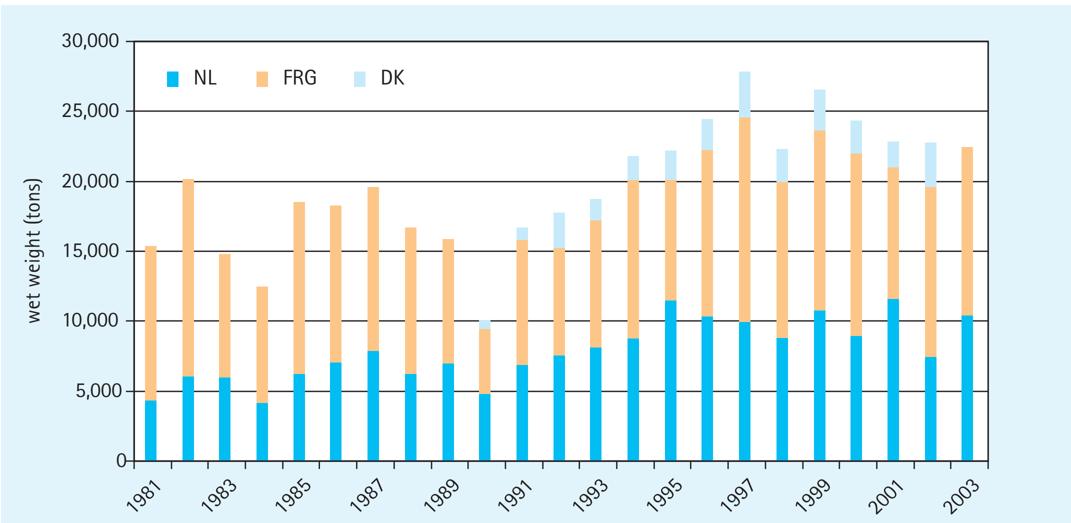


Figure 2.5.4: Landings of brown shrimps in 1981-2003 (in tons wet weight) (sources: DFU, Fischerblatt, PVIS) (DK: data for 1991 – 2002 for Danish vessels).

99 vessels (2003) are mainly involved in shrimp fishery. In Niedersachsen, shrimp fishery was carried out by 101 vessels which were exclusively fishing for shrimps and an additional 35 vessels, normally fishing flatfish, but fished shrimps in that year (in total 136 vessels for shrimp and flatfish fishing in 2003) (Fischerblatt, 2004). Shrimp fishery for animal consumption is regularly carried out in Niedersachsen in the second half of the year. The landings are around 600-1,200 t/yr which is about 20% of the amount landed for human consumption in Niedersachsen.

Since the establishment of the National Park of the Hamburg Wadden Sea in April 1990, fishing of shellfish and shrimp in the core zone of the National Park, which is nearly the entire Conservation and Wadden Sea Area, has been prohibited. According to the National Park Law there are exceptions for fishing shrimp for human consumption in three tidal inlets within the core zone, which are also the only designated and marked navigable waters in the Conservation Area. All other areas outside the Conservation Area and inside the Wadden Sea Area are not suitable for shrimp fishing.

2.5.5.3 Denmark

In the last ten years, between 21 and 27 licensed vessels have fished for shrimps in Danish waters west of the 'Shrimp Line' (SL) drawn between the Wadden Sea islands from the peninsula of Skallingen to Rømø. The SL has been enforced since 1977. In the last ten years, the Danish landings have been on average around 2,000 t (only Danish vessels) and about 3,400 t annually (including vessels from other EU countries) (in Figure 2.5.5 Danish data are total landings including foreign vessels). The main landing harbors are Havneby and Esbjerg.

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2.6 Hunting

Harald Marencic

In the 1999 QSR, an overview of the hunting regulations in the Wadden Sea Area was presented. The major changes in policy and practice regarding hunting is given in the text below.

Trilateral policy and management

Hunting of migratory species has been, or will be, progressively phased out in the Conservation Area or in an ecologically and quantitatively corresponding area in the Wadden Sea Area. (WSP § 9.1.11)

Lead pellets will not be used in the Wadden Sea Area. (WSP § 9.1.12)

Hunting of non-migratory species is, in principle, only allowed in the Conservation Area, if migratory species are not harmed. (WSP § 9.1.13)

(Trilateral Wadden Sea Plan (WSP), 1997)

2.6.1 The Netherlands

In The Netherlands, hunting on migratory species has been legally forbidden in the whole country since 2001 (with major restrictions already in 1999).

Hunting in the Conservation Area (PKB Area) is confined to areas above the mean-high-water level, namely the salt marshes and the dunes, and, outside the Wadden Sea Area, to some inland areas.

The amended Act on Flora and Wildlife got into force in 2002. The Act forbids hunting on non-migratory species in the areas falling under special conservation measures like the Birds Directive areas, which includes large parts of the islands (dunes and salt marshes). Hunting or scaring may only be allowed as a measure for crop damage control. The use of lead pellets is generally forbidden.

2.6.2 Germany

A Federal Decree concerning the hunting seasons was amended in April 2004. Amongst others, the hunting season for harbour seals was suspended reflecting the factual situation since 1974, which is a hunting ban on seals.

In the Hamburg Wadden Sea, hunting is generally forbidden.

In Schleswig-Holstein, hunting has not been carried out in the National Park in the past and is now forbidden according to the National Park Act of 1999 (§ 29 Abs. 4 No. 2 of the Hunting Act). The State Hunting Act was amended in July 2002 with regard to hunting on island and mainland areas. Regular hunting on brent goose (*Branta bernicla*), bean goose (*Anser fabilis*) and gulls is now completely forbidden. Hunting on barnacle goose (*Branta leucopsis*) and wigeon (*Anas penelope*) is allowed in case crop damage occurs (Koffijberg *et al.*, 2003).

In Niedersachsen, hunting in the tidal area ceased completely in 1994. Since 2001, hunting in tidal areas as well as on the uninhabited islands of Mellum, Memmert and Minsener Oog is forbidden according to the State Hunting Act. Hunting on waterfowl is forbidden by the National Park Act in the core zone on the mainland since 2001. On the inhabited islands, there is an open season for hunting on water birds in the core zone during a maximum of 10 days per year. Hunting on hare, rabbit and deer is carried out in some parts of the national park and (more frequently) in inland agricultural areas outside the national park.

Areas without hunting have been established on all islands, in the Leybucht area and some smaller salt marsh areas between Elbe and Weser. Additionally, restrictions concerning hunting intensity have been imposed in the majority of the (mostly state owned) hunting grounds by civil law.

Lead pellets are not used in the German Wadden Sea Area except in Niedersachsen.

2.6.3 Denmark

According to the Statutory Order on the Wadden Sea Nature and Wildlife Reserve, hunting of migratory birds is allowed within the Conservation Area in areas of salt marshes, along the mainland coast and on Mandø and Rømø. Hunting is hence allowed in a narrow strip along the major part of the coast. Hunting is also allowed from anchored vessels and by wading west of a line between the islands from 1 October to 31 January. In compensation, hunting has been forbidden in some state-owned areas on Skallingen, Fanø, Mandø and Rømø. The latter areas are now included in the Reserve as a result of the revision of the Order in 1998, when the Danish section of the Conservation Area has been expanded by some 1,500 ha to include both mainland and island areas.

An advantage of this solution is that a comprehensive area of strict protection has been created in the Ho Bay and Skallingen, which includes the main habitats of the Wadden Sea Area (offshore, dunes, natural salt marshes, tidal area, island). The use of lead pellets, in generally, is forbidden in Denmark.

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2.7 Military Activities

Harald Marencic

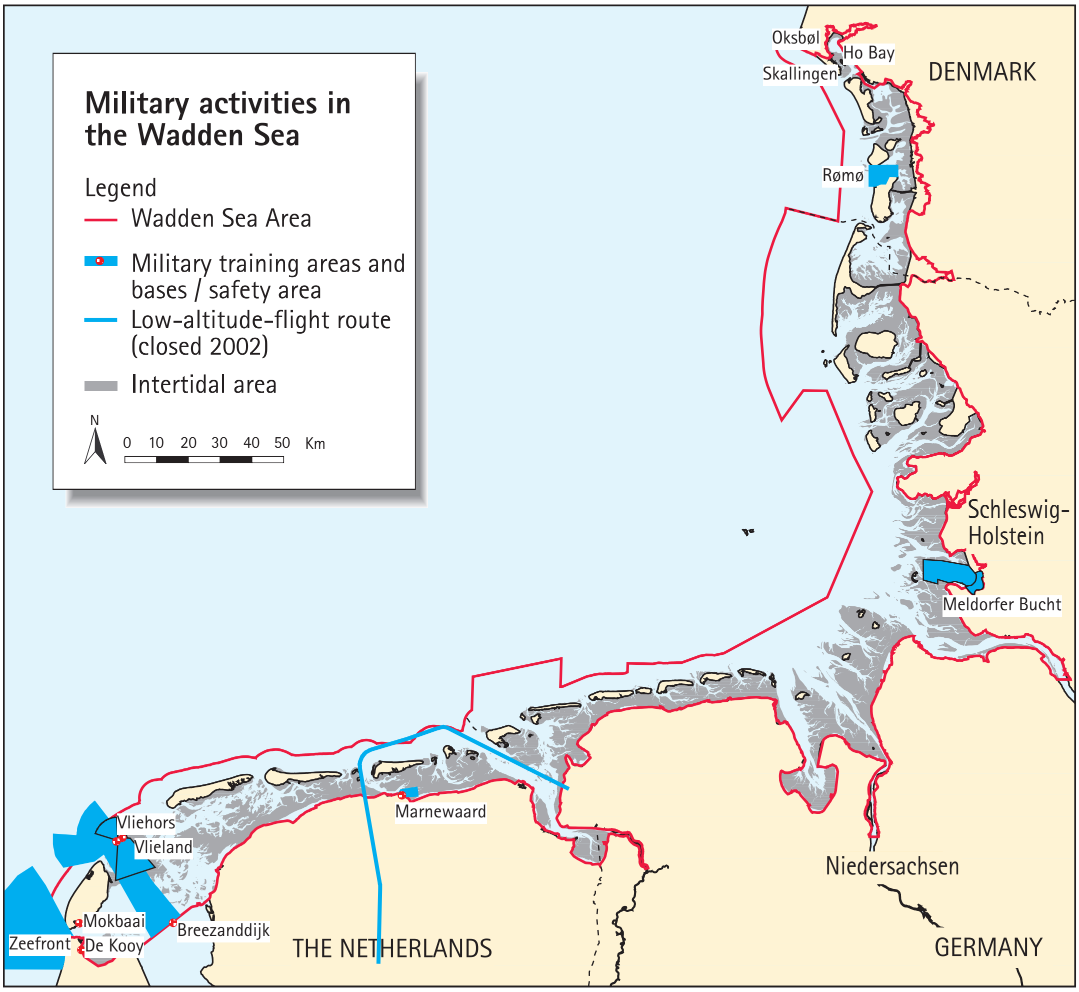

Figure 2.7.1: Military activities in the Wadden Sea Area (from QSR 1999).

The military activities in the Wadden Sea Area involve exercise and shooting ranges for ground forces and aircraft, testing areas for military equipment, low altitude flight and air target areas for military aircraft, and associated flights of aircraft and helicopters.

The main point of military activities is situated in the western Dutch section of the Wadden Sea Area. The 1999 QSR stated that, in general, military activities and exercise areas have been reduced during the last decade in all of the area. Since then, no major new developments could have been reported (Jaarboek Waddenzee, 2002, Joint Progress Report 2001). In The Netherlands, the regulations for military activities is laid down in the 'Structuurschema Militaire Terreinen' which was adopted by Parliament in December 2004. In 2002. the general minimum flight height was raised from 300 to 450 m (with an exception for military helicopters and the approach of the shooting range Vliehoors) and the low-altitude flight route (see Figure 2.7.1) was closed.

A map of the localities of the exercise areas and the activities in the Wadden Sea Area is in Figure 2.7.1.

A recent study revealed that a considerable amount of conventional ammunition was dumped in the coastal areas of the North Sea after the end of World War II (Nehring, 2005).

2.7.1 Military exercise areas

Zeefront

Zeefront consists of relatively small shooting exercise ranges near Den Helder outside the Wadden Sea Area. The anti aircraft artillery range in Den Helder was closed in 2005. Part of the security zone was located within the Wadden Sea Area.

Mokbaai

The Mokbaai entails an amphibian exercise ground with a military barrack and 100 persons permanently stationed. The exercises, involving zodiaks, landing crafts and helicopters of the naval forces, are confined to work days. By planning the exercises, the breeding and moulting periods of birds are taken into account. In order to ensure the navigation of landing crafts the shipping lane in the Mokbaai is regularly dredged.

Breezanddijk

The site is a test shooting range in the IJsselmeer from a position on the Afsluitdijk used about to a maximum of 85 days per year. In 2001 and 2002 it was used 21 and 28 days respectively. The activity does not take place inside the Wadden Sea Area and only limited noise disturbance results from the tests.

Vliehors

The shooting range for NATO-military aircraft is situated on the Vliehors, a large sandbank on the west side of the island of Vlieland. It is used on work days for the firing of guns and rockets and dropping of bombs. Practices with bombs, rockets and gunning from fighter planes occur an average of 180 days per year. In 2002, it was used during 17 weeks. On average, about 3,300 aircraft movements were registered per year during the period 1997–2002.

The security zone is located north of the island off the coast in the Wadden Sea Area. The danger zone, which primarily stretches out into the Wadden Sea (depth 12 km), has a total surface area of 105 km². The target area, including the standing points for shooting, covers a surface area of 1.5 km².

In order to limit disturbance, the dropping of explosive bombs is excluded in the period from 15 April to 1 September.

Furthermore, the flight route has been situated off the coast to limit the disturbance of the neighboring island Texel.

In 2003, the shooting with tanks was stopped at the military site Vliehors and the use of the shooting range was strongly diminished.

Vlieland

The location was used for tank firing and was closed in 2004. The shooting period was confined to 1 September to 15 April in order to limit the disturbance. The security zone was situated south of the island. In 2003, the location was used for 13 weeks in total.

Marnewaard

This shooting range for machine guns is situated directly adjacent to the Wadden Sea Area northeast of the embanked Lauwersmeer and encompasses an area of 2,500 ha. The security zone is situated in the Wadden Sea Area. The shooting range is used to a maximum of 42 days per year (14 weeks per year, three day per week). In 2002, it was in use for 10 weeks and in 2003, due to reconstruction work, for 16 days (WaddenInzicht, 2005).

Trilateral policy and management

Disturbance caused by military activities has been, or will be, reduced and the possibilities for further concentrating and/or phasing out military activities will be regularly examined. (WSP § 9.1.21)

The negative effects of low altitude flight routes of military aircraft have been, or will be, reduced by reducing the number of flights and the maximum speed. (WSP § 9.1.22)

Action to minimize disturbance caused by military air traffic in the Wadden Sea area will be taken on a coordinated basis. (WSP § 9.1.23)

High priority will be given to the assignment of redundant shooting ranges as nature protection areas. (WSP § 9.1.24)

(Trilateral Wadden Sea Plan (WSP), 1997)

Meldorfer Bucht

The Meldorfer Bucht location is a testing site for new weapons by the German Ministry of Defense. The tests are undertaken from platforms on the seawall and the target areas are situated in the Meldorfer Bucht (see map). The security zone covers an area of about 12,000 ha, of which about 10,000 ha are within the zone 1 of the national park. The projectiles are recovered from the Wadden Sea by the use of helicopters and also, to ensure that the area is safe prior to any tests, helicopters fly over the area.

The number of test days has been reduced from 70-90 days to about 10-20 days per year. The tests are mostly carried out from November to the end of March. From mid June to mid September, which is the main moulting time for shelducks and in which the large majority of the total population of shelducks is present in the area, no tests are undertaken. From 1998 on, no further tests have been undertaken until the shooting activities were resumed again in 2001.

Rømø

The northern part of the island of Rømø is a shooting range for NATO-military aircraft for gun and rocket shooting at low altitudes. The security zone covers the northern part of the island and part of the tidal inlet between Mandø and Rømø. A larger area is restricted for air traffic during exercise time. The activities are primarily carried out during summer but, normally, not in July.

Ho Bay, Skallingen and Oksbøl

Ground forces are allowed to carry out landing exercise operations in the Ho Bay and at the coast of Skallingen north of the 55°38´ latitude. The large exercise and shooting range Oksbøl is located north of the Wadden Sea Area. In connection with exercises on the exercise and shooting range in August to September flights are undertaken 1-2 days in the northern Danish Wadden Sea Area in flight corridors.

2.7.2 Other military activities

Other military activities concern the air traffic and associated traffic connected with the use of the exercise areas. In the Dutch Wadden Sea Area, helicopters are, *e.g.*, used as stand-by during exercises on the locations. Specific helicopter routes have been designated to limit the disturbance, for example, off the coast of the islands and the minimum flight altitude is 500-600 feet under normal weather conditions.

In the Dutch Wadden Sea, the recently adopted management plan ('Structuurschema Militaire Terreinen') entails the ultimate closing of the low-altitude-flight route (which crosses area between the island of Schiermonnikoog and Ameland, see Figure 2.7.1), an increase of the minimum flight altitude of military aircraft over the Wadden Sea to 300-400 m and a shift of the approach corridor to the shooting range Vliehors from the Wadden Sea to the open North Sea (Jaarboek Waddenzee, 2002).

In Germany, the minimum flying-altitude for military aircraft was changed in 2002. For major parts of the German Wadden Sea, due to its status as national park, military aircraft must adhere to a minimum flying altitude of 3,000 feet (915 m) for jet aircraft and 2,000 feet (610 m) for all other aircraft including helicopters unless specific operations or weather conditions dictate otherwise.

The Leybucht, the Außenweser and the Jade, including the Jadebusen, belong to a low altitude flying-area with a minimum flying-altitude of 500 feet (152 m).

There are several military airports in the vicinity of the Wadden Sea Area (De Kooy and Leeuwarden in The Netherlands; Jever, Wittmund, Nordholz, Eggebek/Tarp and Kropp in Germany; Skrydstrup, Denmark) but there is no direct relationship with the use of the Area.

2.7.3 Abandoned exercise areas

In addition to the reductions indicated above, three exercise areas have been abandoned:

- Den Helder/Lutjewaard shooting exercise range in the Conservation Area;
- Noordvaarder on the island of Terschelling since 1 July 1995; the exercises have been transferred to the Vliehors; the former exercise area has been cleaned of ammunition remainders; the designation of the area as a nature reserve will be considered in the framework of the overall conservation regime of the islands;
- Königshafen exercise area on the island of Sylt has been abandoned since October 1992; the exercise area was situated outside the Conservation Area.

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2.8 Gas and Oil

Harald Marencic

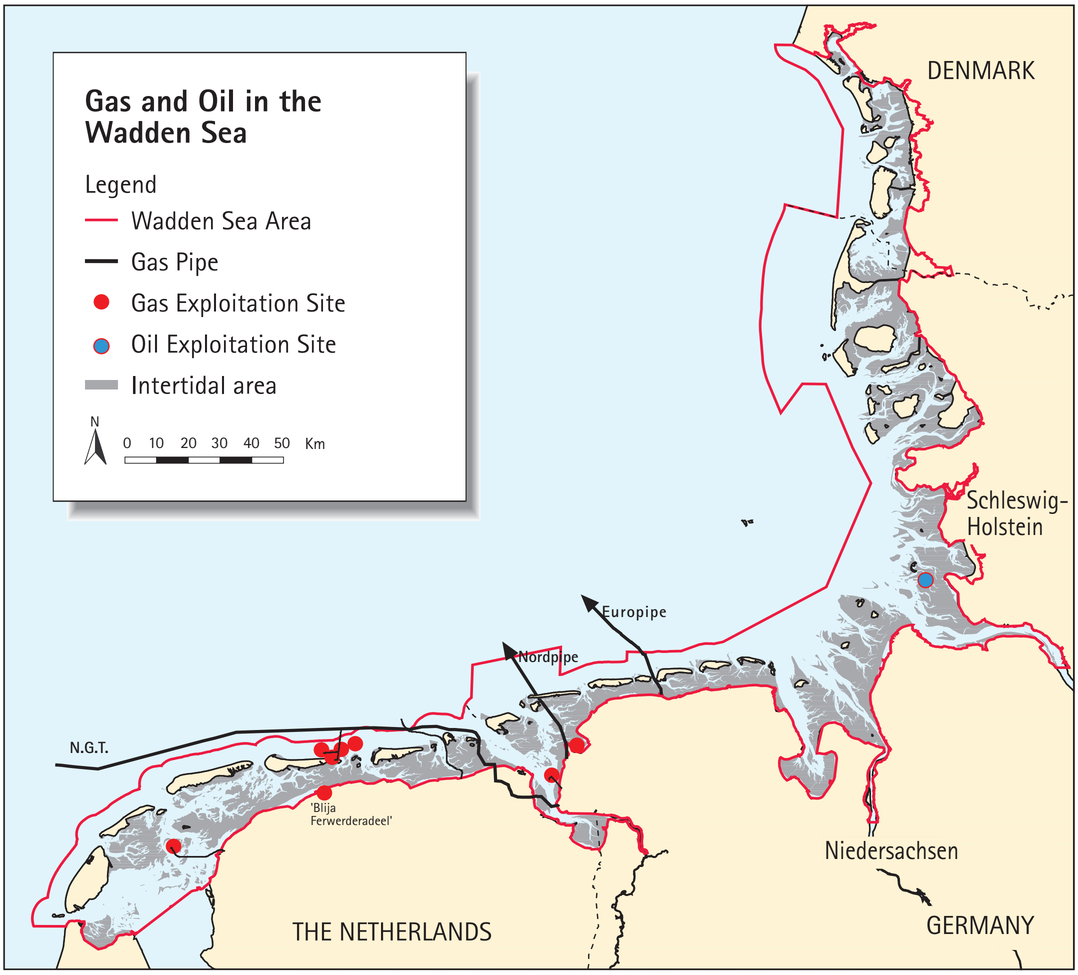


Figure 2.8.1
Gas and oil exploitation sites and pipelines in the Wadden Sea (source: 1999 QSR, Jaarboek Waddenzee 2002).

The 1999 QSR gave a detailed overview on the exploration and exploitation of gas and oil in the Wadden Sea Area. This chapter gives a short overview about the present status and focuses on major new developments since 1999.

An overview of oil and gas exploration and exploitation activities is given in Figure 2.8.1.

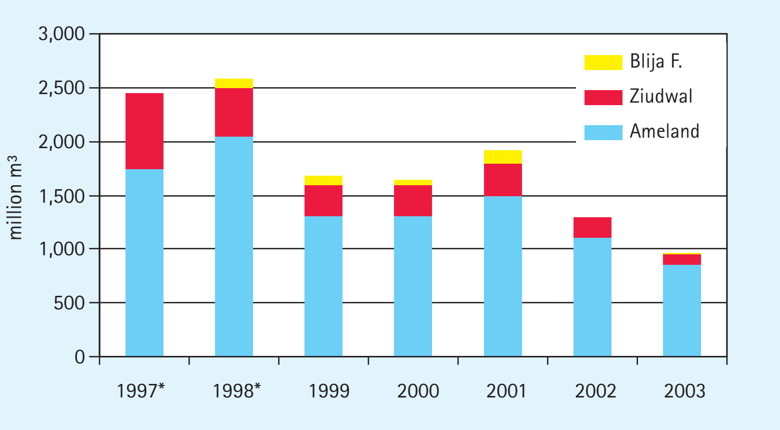
2.8.1 The Netherlands

There are four gas exploitation areas in the Wadden Sea area: the large Groningen field, Ameland, Blija and Zuidwal. There are two areas for future exploitation: Moddergat and Lauwersoog. Zuidwal is located in the Dutch Conservation Area (PKB). The proven total gas reserve in the Dutch Conservation Area has been estimated by the NAM at about 40 billion m³. About 80% can be produced through existing infrastructure. These fields are situated north of the exploration locations Moddergat and Lauwersoog from which 5 wells were drilled under the Wadden Sea in the period 1994 till 1998. According to TNO-NITG, the additional futures (potential non-proven reserves) are estimated between 30 and 130 billion m³. This is in agreement with estimates of NAM. The Ministry of Economic Affairs, estimates the reserves between 25 and 35 billion m³ and estimates the futures at 42 billion m³. For exploring the Wadden Sea futures, no detailed plan exists at this moment. An EIA procedure to take Lauwersoog and Moddergat in production was started in 2005.

The exploitation of natural gas at the 'Zuidwal' concession area (Vermilion) in the middle of the western part of the Dutch Wadden Sea near Harlingen concerns a deposit which has been estimated to encompass about 22 billion m³ of exploitable natural gas. Exploitation started in 1989. A new well was drilled in 2004. The natural gas is exported via a pipeline to a treatment installation at Harlingen. All solid wastes from the exploitation site are transported to land and the produced water is returned to the reservoir.

In the Noord Friesland concession area (NAM/Mobil), which extends over the mainland, the Conservation Area and the Wadden Sea Area. On Ameland, three sites have been situated on the island itself. On the west cape, the Hollum location (non-producing), close to Ballum an exploration site (not operational) and on the east cape an active production site ‚Ameland-Oost'. At sea,

Figure 2.8.2: Gas production (in million m³) in the Dutch Wadden Sea (source: Jaarboek Waddenzee; * = approximate figures).



a small satellite platform and a larger production platform ‚Ameland-Westgat' are situated north of Ameland at about 3 km offshore. At the latter platform, the gas is purified and dried before transport. Solid wastes are transported to shore and the produced water is returned to the reservoir. Due to the decreased gas pressure in the reservoir, the gas needs to be recompressed at a separate, but connected compression platform. Via the so-called NGT pipeline, which runs north of the islands and crosses the Wadden Sea east of Rottumeroog (Figure 2.8.1) the high-calory gas is transported to shore.

In the channel between Ameland and Schiermonnikoog a third structure was build, a so-called monopile. The monopile is not yet connected to Ameland and is called N7. The monopile contains 3 wells, connecting to gas fields under the coastal zone and awaiting further development.

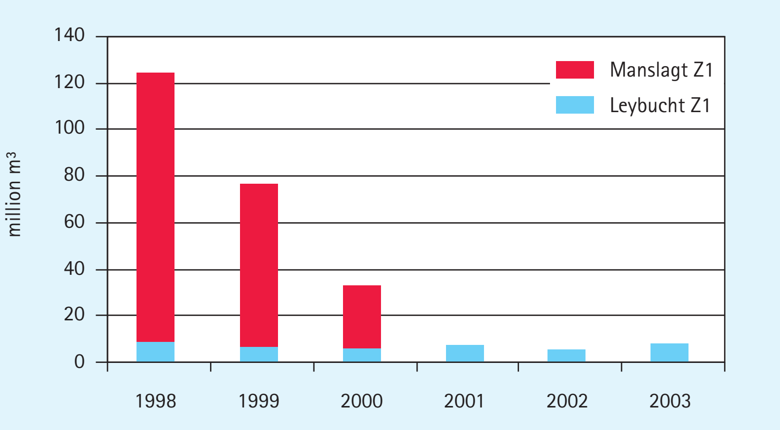
The potential impact due to subsidence, caused by the gas production has been monitored since 1987. In March 2000, the report and program was presented to the public and discussed with a number of independent experts at the University of Groningen (Begeleidingscommissie Monitoring Ameland, 2000). No significant impact was found and no loss of natural values after 13 years of gas production and 18 cm of subsidence (de Vlas and Marquenie, 2003). In general, the measured impact was far less as predicted in 1987 (Marquenie and de Vlas, 2005). The program was improved based on the public debate and continued for another 10 years. Public reports will be prepared every five years.

In 2003, additional measures were taken on the Ameland offshore production platforms in order to reduce the light intensity. The measures are aimed to mitigate the potential disturbance and desorientation of migrating birds.

Adjacent to the Wadden Sea Area, there is the production site 'Blija Ferwerderadeel' located on the mainland coast and also producing from under the Wadden Sea. The total gas production decreased from about 2.5 in 1997 to about 1 billion m³ in 2003 (see Figure 2.8.2). For comparison, the gas production in the 'Groningerveld' was 33.5 billion m³ in 2003.

The prognoses for subsidence caused by gas extraction in the Ameland area was recalculated in 2003, taking into account the already assessed subsidence. This allowed for a much more accurate prediction for the remainder period. The total

Figure 2.8.3: Gas production in the Niedersachen Wadden Sea (in million m³) (source: WEG Jahresberichte).



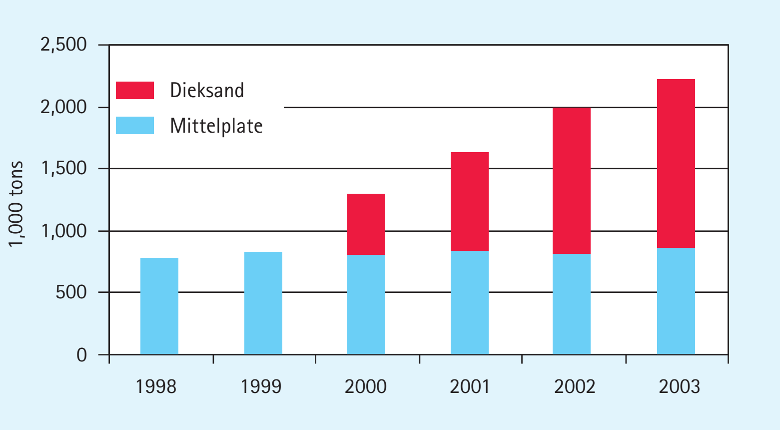


Figure 2.8.4: Oil production Mittelplate (in tons) (source: WEG Jahresberichte 2000, 2003).

subsidence in the center is now estimated to amount to 31-37 cm (mid-value 34 cm) in 2020 after the closure of the field in 2018. The new prognoses was published as part of the new mining law as a document for public consultation.

2.8.2 Germany

Concessions cover most of the German part of the Wadden Sea (see Figure 2.8.3). To date, zero-discharges are applied at all installations in the German Wadden Sea Area.

2.8.2.1 Niedersachsen

There are two sites where natural gas is exploited in the Niedersachsen Wadden Sea Area. 'Leybucht Z 1' in the exploitation field 'Juist-Leybucht I' of the concession area 'Juist' is situated in the Conservation Area: The production started in 1977. 'Manslagt Z 1' in the exploitation field 'Groothusen II' of the concession area 'Groothusen' is situated in the Ems estuary outside the Conservation Area. The production started in 1993 and stopped in

Trilateral policy and management

Discharges from oil and gas exploration and exploitation activities

The exploration and exploitation of the energy resources in the North Sea, as well as in the Wadden Sea Area, has to comply, at least, with the international agreements in the appropriate fora. This results i.a. in a prohibition to discharge oil-based muds and cuttings. Dumping or discharge of water based muds and/or cuttings is only allowed in line with relevant PARCOM agreements. (WSP § 2.1.8)

The leaching of toxic substances from protective coatings of pipelines and other installations will be avoided by the use of appropriate materials. (WSP § 2.1.9)

In the Conservation Area, offshore activities that have an adverse impact on the Wadden Sea environment will be limited and zero-discharges will be applied. In the Wadden Sea Area outside the Conservation Area, discharges of water-based muds and cuttings will be reduced as far as possible, by applying Best Available Techniques and by prohibiting the discharge of production water from production platforms. (WSP § 2.1.10)

Infrastructural works

New infrastructural works which have a permanent or long-lasting impact should not be established in salt marshes. (WSP § 3.1.14)

New licenses for the construction of pipelines in the salt marshes for the transport of gas and oil shall not be issued unless such measures are necessary for imperative reasons of overriding public interest. In that case, the method of construction and the planning of the location line shall be such that the environmental impact on the Wadden Sea ecosystem is kept to a minimum and permanent, or long lasting, negative impacts are avoided. (WSP § 3.1.16; Reference to 4.1.13)

Mineral extraction and infrastructure

In the Conservation Area, new exploitation installations for oil and gas will not be permitted. Exploration activities are permitted within the Conservation Area if it is reasonably plausible that deposits can be exploited from outside the Conservation Area. Net loss of nature value must be prevented. Therefore, exploration activities will be regulated in space and time.

Associated studies, mitigation and compensation measures should be carried out where appropriate. (WSP § 4.1.10)

The construction and planning of pipelines shall be such that the environmental impact on the Wadden Sea ecosystem is kept to a minimum and permanent, or long lasting, negative impacts are avoided, and if this is not possible, compensated. In the Conservation Area, new licenses for the construction of pipelines in the tidal area for the transport of gas and oil shall not be issued unless such measures are necessary for imperative reasons of overriding public interest and if no alternative can be found. (WSP § 4.1.13; Reference to 3.1.16)

In order to prevent a further loss of dune areas, the existing infrastructure will, in principle, not be extended and new constructions will, in principle, not be allowed. (WSP § 5.1.4)

(Trilateral Wadden Sea Plan (WSP), 1997)

October 2000 because of an occlusion of the drillhole. It is currently investigated whether the production can be resumed.

Currently the concessionaires are not planning any exploration and exploitation activities within the boundaries of the Niedersachsen part of the Conservation Area (National Park). Seismic investigations have not been carried out in the Niedersachsen Wadden Sea Area in the last few years.

Gas is transported from the Norwegian continental shelf of the North Sea via the Nordpipe pipeline to the Phillips Petroleum treatment plant 'Rysumer Nacken' west of Emden and the 'Europipe I+II' which has been in operation since October 1995 (see Figure 2.8.1).

2.8.2.2 Hamburg

According to the Act on the Hamburg Wadden Sea National Park, it is prohibited to explore and exploit energy resources in the Hamburg Wadden Sea Area.

2.8.2.3 Schleswig-Holstein

According to the Act on the National Park Schleswig-Holstein Wadden Sea, the exploitation of natural oil reserves is only permitted in the region of the Mittelplate and the Hakensand south of Trischen situated in the southern part of the Schleswig-Holstein Conservation Area (National Park). This requires specific approval by the responsible ministry. In 1985, the consortium Mittelplate initiated the construction of the exploitation site 'Mittelplate A', the production started in 1987.

According to current estimates by the consortium running Mittelplate (RWE Dea and Wintershall) there are still more than 100 million t of crude in several layers of oil-bearing sandstone at depths between 2,000 and 3,000 meters. Around 60 million t are considered to be recoverable.

In 1998, drilling operations started to exploit part of the oil from the eastern section of the 'Mittelplate' field from the mainland. In 2000, onshore production started at the Dieksand land station in Friedrichskoog.

The crude oil is transported daily from the platform Mittelplate to Brunsbüttel by three specially constructed tankers and from here pumped to the refinery near Hemmingstedt. Oil production is therefore restricted by transport capacity and tidal regime. In 2003, the State Mining Authority approved plans for a pipeline link between the Mittelplate production site and the Dieksand land station in Friedrichskoog (Mittelplate Konsortium, 2004). The pipeline construction in the Wadden Sea is scheduled for the period March - May 2005 in order to avoid disturbance of moulting geese.

2.8.3 Denmark

The Danish part of the Wadden Sea is part of the concession area of the North Sea but licenses are not issued and, according to the Statutory Order on the Nature Reserve Wadden Sea, exploitation of gas and oil in the Danish part of the Conservation Area is prohibited.

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2.9 Wind Energy

Harald Marencic

Horns Rev wind farm (Photo: Elsam A/S)

2.9.1 Introduction

In the Wadden Sea Conservation Area, the construction of wind turbines is prohibited in all three countries according to the Danish Statutory Order, the German National Park Acts and the Dutch Conservation Area (PKB area).

In the rest of the Wadden Sea Area – on the islands and the adjacent mainland outside the Wadden Sea Conservation Area – the construction of wind turbines and wind farms is only allowed if important ecological and landscape values are not negatively affected.

Policies are in force regarding the construction of wind turbines outside the Wadden Sea Area (along the coast and off-shore) which take into consideration landscape and ecological criteria.

The following chapters focus on development in the Wadden Sea Area and the adjacent offshore area.

Trilateral policy and management

The construction of wind turbines in the Conservation Area is prohibited. (WSP § 1.1.4, identical with 9.1.9).

The construction of wind turbines, in the Wadden Sea Area outside the Conservation Area, is only allowed if important ecological and landscape values are not negatively affected. (WSP § 1.1.5, identical with 9.1.10).

(Trilateral Wadden Sea Plan (WSP), 1997)

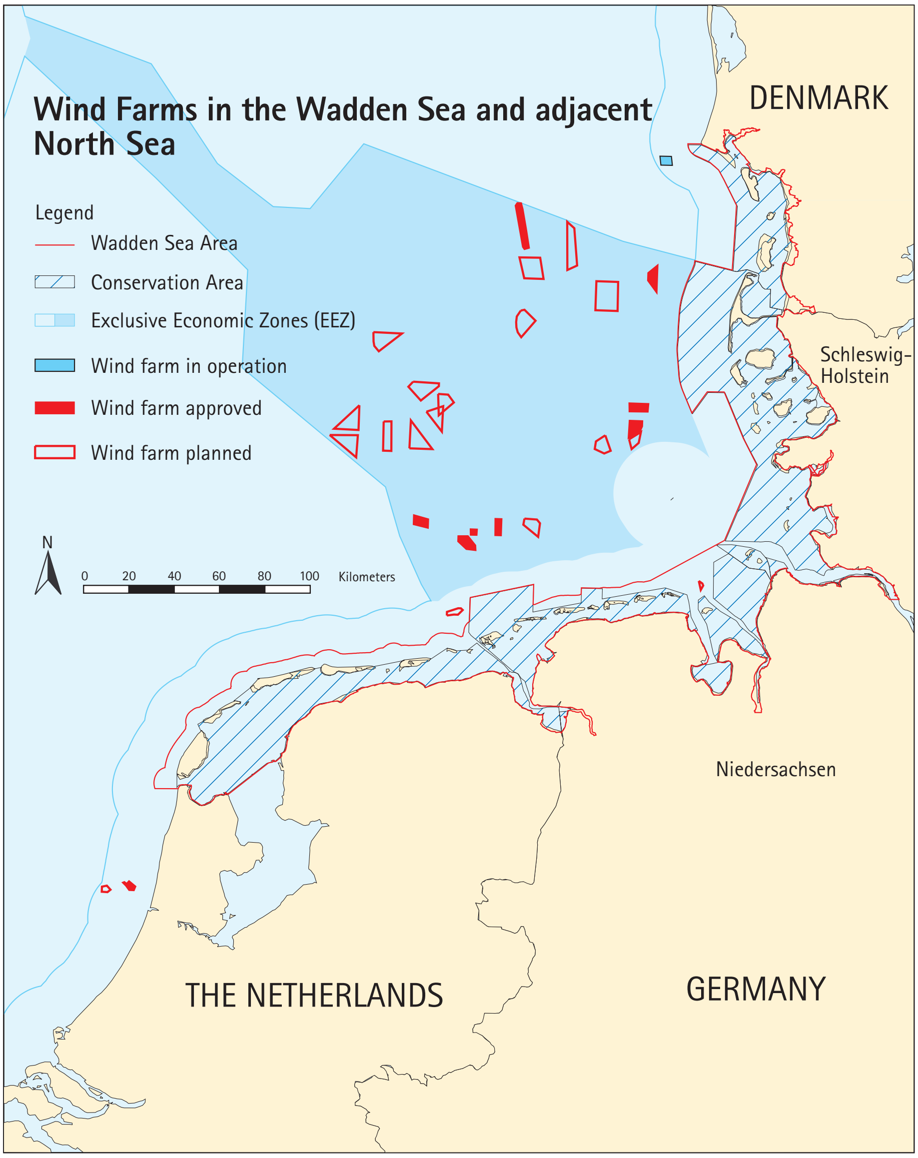
2.9.2 The Netherlands

The construction of wind turbines is not allowed in the Dutch Wadden Sea Conservation Area (PKB area). According to the Dutch Wadden Sea Management Plan (Beheersplan), generating wind energy is only allowed in an area of 1-2 km outside the Dutch part of the Conservation Area if adjacent to suburban areas.

Table 2.9.1: Offshore wind farm projects in The Netherlands

Name	Capacity (MW)	Location	Characteristic	Status
Wind Farm Q7-WP (outside 12 sm)	120	24 km west of Egmond an Zee (Noord Holland)	60 turbines (2 MW)	Permit licensed to E-Connection (February 2002), building will probably start in 2005
Near Shore Windpark 'Egmond' (inside 12 sm)	100	8 - 18 km west of Egmond an Zee (Noord Holland)	36 turbines (2.75 MW), starting with 3 turbines	Building license published and now in juridical procedure
Location Beverwijk 'Corus'		Near shoreline, near Egmond (Noord Holland)		Application for license in preparation
Location Maasvlakte		Near shoreline, Massvlakte (Zuid-Holland)		Application for license in preparation

Figure 2.9.1: Offshore wind farms in the North Sea adjacent to the Wadden Sea (status February 2005). In the German EEZ, only pilot projects are shown, further extension areas of wind farms are not indicated.



There are no plans or permits in the territorial sea north or west of the Wadden Sea; this area has been closed for wind turbines according national spatial policy.

In the Netherlands, there are currently four offshore wind farm projects in different stages of licensing, which are located at the west coast (off Egmond an Zee) (Table 2.9.1, Figure 2.9.1).

2.9.3 Germany

In Germany, a political aim was set to build offshore wind turbines with an installed capacity of around 20,000-25,000 MW by the year 2030. The development of this renewable energy production will be carried out under the precautionary principle in a step-by-step approach and in an ecologically and economically compatible way. In the first phase (up to 2006), about 500 MW and in the mid term (up to 2010) about 3,000 MW could be achieved. By 2030, about 15% of the electric power production could be delivered by offshore wind energy. The aim is to increase the share of electricity consumption generated by wind power on- and offshore to at least 25 % within the next thirty years (BMU, 2002).

An overview of offshore wind farm projects in Germany is given separately for territorial waters (up to 12 sm) and the German EEZ, because the competences for the licensing procedure of offshore wind farms and their cables vary in the EEZ and the 12 sm zone. In the EEZ the Federal Government is responsible and the licensing procedure falls under the Offshore Installations Ordinance ('Seeanlagenverordnung') whereas in the 12 sm zone the German 'Länder' are responsible and carry out regional planning procedures. The con-

Table 2.9.2: Offshore wind farm demonstration projects within 12 sm zone in Niedersachsen (sources: BR Weser-Ems; BR Lüneburg).

Name	Capacity (MW)	Location	Characteristic	Status
Nordergründe	125	between Wangerooge and Cuxhaven	25 turbines, each 5 MW	Spatial planning concluded in December 2003, environmental assessment in preparation
Riffgat	198	15 km northwest off Borkum	44 turbines	EIA in preparation

struction of wind turbines along the coastline is also subject to the national building regulations ('BauGB'). Thorough Environmental Impact Assessments are carried out both in the EEZ and in the 12 sm zone. The German Renewable Energy Sources Act (EEG), which is also applicable for EEZ and 12 sm zone, contains a regulation that electricity from offshore wind farms will only be eligible for payment if sited outside of nature and bird conservation areas. This measure is designed to discourage intervention in these protected Natura 2000 areas.

The routing of cables from offshore wind farms to the mainland power grid network is currently under discussion. In December 2004, a cable connection from the wind farm 'Borkum West' via the island of Norderney to the mainland was approved.

2.9.3.1 Niedersachsen

In the Conservation Area, the construction of wind turbines is prohibited but exemptions are possible, for example, on the islands (see 1999 QSR).

Within the regional planning program, a proposal for two offshore wind energy areas within the 12 sm zone was endorsed in December 2003 by the Government. It concerns the area 'Riffgatt' (15 km off the island of Borkum) and 'Nordergründe' (near the Weser mouth) (Table 2.9.2, Figure 2.9.1).

With regard to cable routing, a decision was taken in September 2004 to connect the wind farm 'Nordergründe' to the mainland power grid in Wilhelmshaven.

2.9.3.2 Schleswig-Holstein

According to ordinance, the construction of wind turbines is not allowed in the Wadden Sea Conservation Area. The same is valid for all Halligen, the geest parts of the islands Amrum, Föhr and Sylt, geological formations under protection as well as the areas seaward of the dikes in the Wadden Sea Area. Wind energy installations are not allowed in, or close to, feeding and roosting areas for birds. Generally, distances of 50-1000 m from these areas have to be respected.

At the moment, there are wind energy installations on the islands of Föhr (twelve wind turbines), Pellworm (six) and Nordstrand (seven) with an average and maximum power of 220 kW and 800 kW, and average and maximum height of 30 m and 42 m and an average and maximum rotor-diameter of 23.7 m and 31 m.

2.9.3.3 Hamburg

The construction of wind turbines is not allowed in the entire Hamburg Wadden Sea Area.

2.9.3.4 German North Sea EEZ

Outside the 12 mile zone, in the German EEZ, the Federal Maritime and Hydrographic Agency (BSH) is in charge of licensing offshore wind farm

Table 2.9.3: Overview of approved offshore wind farm pilot projects in the German North Sea EEZ (outside territorial waters >12 sm) (sources: BSH, February 2005; OSPAR, 2005).

Name (company)	Capacity (MW)	Location	Characteristic	Status
Borkum West (Prokon Nord)	60	45 km north of Borkum	12 turbines in pilot phase (planned 208)	Approved November 2001
Borkum Riffgrund-West (Energiekontor)	280	50 km northwest of Borkum	80 turbines in first phase (planned 485)	Approved February 2004
Borkum Riffgrund (PNE2 Riff I GmbH)	750	38 km north of Borkum	77 turbines in first phase (panned 180)	Approved February 2004
Amrumbank West (Amrumbank West GmbH)	400	36 km southwest of Amrum	80 turbines	Approved June 2004
Nordsee Ost (Winkra mbH)		30 km northwest of Helgoland	80 turbines in first phase (planned 170)	Approved June 2004
Butendiek (Butendiek GmbH)	240	34 km west of Sylt	80 turbines	Approved December 2002
Sandbank 24 (Sandbank 24 GmbH)	280	90 km west of Sylt	80 turbines in pilot phase (planned 900)	Approved in August 2004
North Sea Windpower (Enova GmbH)	240	40 km north of Juist	48 turbines in pilot phase	Approved in February 2005

Table 2.9.4: Offshore wind farms in the Danish part of the North Sea (source: Skov- og Naturstyrelsen).

Name	Capacity (MW)	Location	Characteristic	Status
Horns Rev	160	14 – 20 km off Skallingen	80 turbines	In operation since 2002
Rønland	17	1 km off the coast (Limfjord)	8 turbines	Permission given in 2002 In operation since 2003

projects. In December 2004, about 24 projects were in some kind of planning stage for sites in the North Sea (BSH, 2005, Figure 2.9.1). In Table 2.9.3, an overview is given of the pilot projects which have been approved by the BSH until February 2005.

2.9.4 Denmark

The Danish Government's energy action plan 'Energi 21' targets a reduction in CO_2 emissions by 50% by 2030 (as compared to 1988). As the erection of additional land-based wind farms would create unacceptable concentrations of wind turbines, the target is to establish 4,000 MW at sea by 2030. In the first phase up to 2008, a capacity of 705 MW should be achieved (5 sites, each 120 to 150 MW).

At the moment, two wind farms are in operation in the North Sea (Table 2.9.4), with the Horns Rev wind farm as the biggest one (ELSAM, 2005).

An additional seven wind farms are in operation in the Baltic Sea (total 250 MW). There are procedures going on to develop one or two more sites, with a combined capacity of about 500 MW.

In the Danish Conservation Area, there are no wind turbines, and the construction of wind turbines will not be allowed here, although nothing is particularly mentioned in the newly revised Statutory Order for the Conservation Area, which came into force on 1 March 1998. According to § 13-4 of the Statutory Order, the construction of wind turbines is not allowed in the sea territory of the Wadden Sea Area. In accordance with the regional planning documents of the counties, no new wind turbines will be allowed in the Wadden Sea Area.

In the Wadden Sea Area (outside the Conservation Area), there is one farm (sixteen turbines) at the northern part of the island of Fanø (established around 1983) and a group of three turbines in the northern part of Ho Bugt (established around 1990). The farm and group are both encompassed by a local planning scheme and can be replaced by similar new ones in accordance with these plans.

On the mainland outside the Wadden Sea Area, there are scattered areas on the geest where single and groups of turbines and wind farms are located: east of Esbjerg, near to the salt marshes of Måde; in the Tjæreborg marsh; a wind farm at Hjerpsted Bakkeø up to the Wadden Sea; a few wind turbines in Tønder Marsh and a reservation area for large wind turbines in the lower geest up to the marshlands north of the river Konge Å.

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2.10 Extraction of Sand and Shells

Karel Essink
Harald Marencic

In the 1999 QSR detailed statistics on sand extraction were presented. The text below merely presents the major changes in policy and practice regarding extraction of sand and shells from the cooperation area. The operative trilateral policy and management is presented in the colored box.

2.10.1 The Netherlands

2.10.1.1 Shells

A new national policy on shell extraction was formulated in 1998 (VenW, 1998), which included additional investigation of gaps in knowledge (Reijngoud, 2001). Since 2002, the national policy was revised (VenW, 2001). As a consequence, 210,000 m³ of shells were allowed to be extracted annually, of which 90,000 from the Wadden Sea proper, and 120,000 from the outer delta's and the coastal zone. The coastal zone directly bordering the islands is closed because of absence of exploitable shell deposits. Licenses granted allow stationary dredging only.

In 2003, the amount of extracted shell (about 64,000 m³ in the Dutch Conservation Area, and 70,000 m³ in the outer Wadden Sea) was below the maximum quota (Interwad, 2005).

In 2004, an evaluation was made, taking into account morphologic behaviour of extraction pits, ecological effects, natural calcimass production and exploitability (van der Meulen, 2004) and the national policy was revised. The two most important changes include a closing of areas where yields were low and limitation of shell extraction to three locations.

The total allowable amount of shells to be extracted is based on long-term average of natural production and is now fixed at 190,000 m³/yr (previously 210,000 m³/yr) and will be further decrease towards 171,000 m³/yr. Extraction is not allowed anymore in the tidal inlets Eierlandsche Gat, Zeegat Ameland and Lauwers. Any extraction in the Ems estuary remains subject to the Environment Protocol (1996) of the Ems-Dollard Treaty between The Netherlands and Germany.

An issue for further attention is the importance of subtidal shell deposits for epibenthic biodiversity. This is being studied in an area in the eastern Dutch Wadden Sea with an initial survey carried out in 2002/2003. The study will be evaluated not earlier than 2009.

2.10.1.2 Sand

In the course of 1998 commercial sand extraction in the Wadden Sea was phased out completely. In 1998, a total of 516,000 m³ of sand was extracted mainly from navigational channels in the Dutch Wadden Sea. No new licences have been granted. Commercial sand extraction was moved to the North Sea outside the 20 m depth contour.

From 1999 onwards, extraction of sand is allowed only as a side product of necessary maintenance dredging in navigational routes. This resulted in the extraction of 79,000 m³ (in 1999), 86,000 m³ (in 2000), 88,000 m³ (in 2001), 329,000 m³ (in 2002) and 436,000 m³ of sand in 2003.

2.10.2 Germany

2.10.2.1 Shells

The extraction of shells in the German National Parks is not allowed. For the Ems-Dollard area, policies with regard to shell extraction will be laid

Trilateral policy and management

The extraction of sand in the Conservation Area will be limited to the dredging and maintenance of shipping lanes. This sand can be used for, inter alia, sea defense purposes. In specific cases, sand may also be extracted for sea defense purposes. (WSP § 4.1.11)

The extraction of sand in the Wadden Sea Area outside the Conservation Area should make maximum use of sand generated by the maintenance of shipping lanes. It should be carried out in such a way that the environmental impact is kept to a minimum and permanent, or long lasting, effects are avoided and, if this is not possible, compensated. Permits for small scale extractions of sand will remain in force. Small scale extractions of mud and sea water for medical purposes will remain permitted. (WSP § 4.1.12)

Increased attention will be given to the role of the offshore zone in the total Wadden Sea sand balance. (WSP § 7.1.2)

Sand extraction will only be carried out from outside the Wadden Sea Area. Exemptions for local coastal protection measures may be granted, provided it is the Best Environmental Practice for coastal protection. (WSP § 7.1.3)

With regard to the extraction of shells, the Wadden Sea Plan announces a study into the shell production in the Wadden Sea Area with the aim of obtaining information on natural accretion, on the basis of which new quota for sustainable shell extraction will be fixed. (WSP § 4.2.5)

(Trilateral Wadden Sea Plan (WSP), 1997)

Table 2.10.1: Amounts of sand extractions and sand nourishment (m^3) in Schleswig-Holstein.

	1999	2000	2001	2002	2003
Sylt	706,000	1,674,000	1,068,000	948,000	948,000
Föhr	0	422,000	0	0	0
Hooge	0	0	42,000	0	0

down in the Environmental Protocol of the Ems-Dollard Treaty between The Netherlands and Germany.

2.10.2.2 Sand

Sand extraction for commercial purposes is not allowed in the Niedersachsen National Park. Sand is only extracted for dredging of shipping lanes and coastal defence purposes.

Sand extraction in the Hamburg National Park is not allowed.

In the Schleswig-Holstein National Park, no sand for commercial purposes is extracted. In the period 1999-2003, on average 1.1 million m^3 per year was extracted for coastal defense purposes. Between 1999 and 2003 about 5.4 million m^3 of sand have been nourished at Sylt, and 0.4 million m^3 at Föhr (chapter 2.1).

In the Wadden Sea outside the Conservation Area (National Parks) sand has been extracted 13 km west of the island Scharhörn (location 'Delphin', size about 920 ha) since 2002. The sand is used for the expansion of premises of Airbus industries in Hamburg; the total amount of sand to be extracted will be about 8 million m^3. In this context, compensation measures were realized at the island Neuwerk.

Adjacent to the Wadden Sea, two sand extraction areas (HBH 1, Brewaba 1) are in a planning procedure. They are located near Nordergründe outside of the Wadden Sea Area. It is planned to extract about 20 million m^3 of sand from an area of about 900 ha.

2.10.3 Denmark

2.10.3.1 Shells

The extraction of shells is not allowed in the Danish part of the Wadden Sea Area.

2.10.3.2 Sand

The extraction of sand for commercial purposes is not allowed in the Danish part of the Wadden Sea Area. Permission for the extraction of sand for sea defense purposes may be granted if such material cannot be found behind the dike or can not be collected in combination with the deepening of shipping lanes.

In the past years, the possibility of using dredged material for sea defense purposes has not been used.

Sand extracted for deepening of shipping lanes to Esbjerg and Fanø and is dumped back into the system (see chapter 2.11).

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2.11 Dumping of Dredged Material

Harald Marencic

Material dumped into the Wadden Sea mainly originates from dredged material removed for the maintenance of shipping lanes. In specific cases, dredged material may be used for sea defense purposes.

Trilateral policy and management

The impact of dumping dredged materials will be minimized. Criteria are, amongst others, appropriate dumping sites and/or dumping periods. (WSP §§ 4.1.15; 6.1.13)

(Trilateral Wadden Sea Plan (WSP), 1997)

The amounts of dredged material dumped into the whole Wadden Sea Area varied between about 9-26 million t/yr (dry weight) during the period 1998 - 2003 (average 14.8 million t/yr) (see Table 2.11.1 and Figure 2.11.1). On average, 12.3 million t/yr (dry weight) were dumped into the German part of the Wadden Sea, 1.4 million t into the Dutch and 1.3 million t into the Danish Wadden Sea. The dumping sites and the average amount for each region are shown in Figure 2.11.2.

Because maintenance dredging is the main source of dumped material, the amounts depend mainly on natural variation of sedimentation and resuspension processes. In general, no trend in the amounts of dredged material dumped into the Wadden Sea can be observed. However, since 1999, yearly amounts have been decreased in the Elbe, Jade and Weser areas compared to the years before (Figure 2.11.1). A comparison with earlier data before is difficult to be made because the reporting requirements to OSPAR changed from tons wet weight of dredged material to tons dry weight in 1995.

Reference values of dredged material, so-called 'Action list levels', should be developed on regional basis. An overview on national action levels for dredged material is given by OSPAR (OSPAR Commission, 2004a). Most countries use a '3 category action level' approach in which two discriminatory concentration levels are used. Concentrations of contaminants in the material falling below the lower limit represent those of little concern. Those falling between the lower and the upper concentration level may trigger further investigation of the material proposed for dumping. Those concentrations above the upper level generally mean that dumping of the material at sea is not permitted. Where action levels have not been developed, a 'case by case' approach is taken for each application considered individually (OSPAR Commission, 2004a).

As Contracting Parties to the OSPAR Convention of 1992, The Netherlands, Germany and Denmark are obliged to report each year to the OSPAR Secretariat on all dumping operations of the previous year. The 'OSPAR Guidelines for the Management of Dredged Material' were adopted in 1998, revised in 2004 and are being implemented in national guidelines (OSPAR Commission, 1998, 2004b).

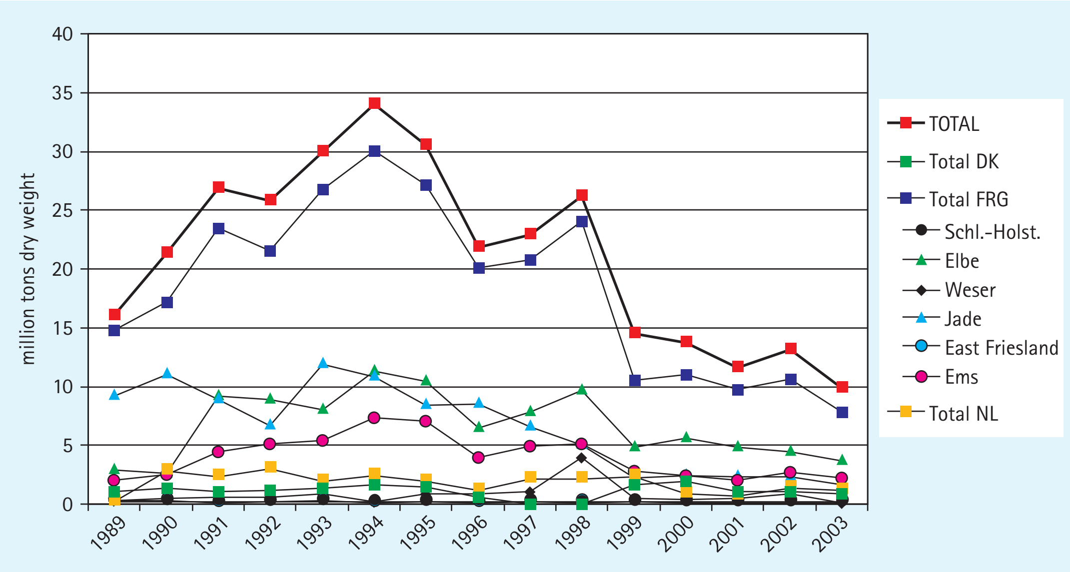
2.11.1 The Netherlands

The amounts of dredged material dumped into the Dutch Wadden Sea did not show significant changes during the period 1998-2003 and vary between 0.8-2 million t (dry weight) per year (see Table 2.11.1) with an annual average of 1.4 million t which is a slight decrease compared to the

Area	OSCOM Code	1998	1999	2000	2001	2002	2003	average/year
Germany								
Schlesw.-Holst.	D10-13,40,49, 52,53	124,000	164,000	108,000	85,000	122,000	63,000	111,000
Elbe	D14,47	9,653,000	4,830,000	5,574,000	4,800,000	4,445,000	3,718,000	5,503,333
Weser	D15,16,39,46	3,974,000	447,000	412,000	460,000	888,000	57,000	1,039,667
Jade	D17-20,41,42	5,030,000	2,175,000	2,375,000	2,315,000	2,348,000	1,609,000	2,642,000
East Friesland	D21-28,30-33, 36,43-45,50	159,000	167,000	156,000	152,000	153,000	155,000	157,000
Ems	D34,37-38	5,158,000	2,760,000	2,391,000	1,988,000	2,673,000	2,188,000	2,859,667
Total FRG		**24,098,000**	**1,0543,000**	**1,1016,000**	**9,800,000**	**10,629,000**	**7,790,000**	**12,312,667**
Netherlands								
West	NL13	425,414	473,136	838,408	714,427	437,772	345,826	539,164
Middle	NL14	880,637	773,680	0	0	507,758	542,098	450,696
East	NL15	785,903	1,068,436	0	0	453,873	311,310	436,587
Total NL		**2,091,954**	**2,315,252**	**838,408**	**714,427**	**1,399,403**	**1,199,234**	**1,426,446**
Denmark								
Esbjerg	RIB01-08	n.d.	1,583,165	1,891,415	1,071,786	1,093,500	834,739	1,294,921
Rømø	SJ-02	n.d.	31,350	14,835	14,705	10,949	15,420	17,452
Total DK		**n.d.**	**1,614,515**	**1,906,250**	**1,086,491**	**1,104,449**	**850,159**	**1,312,373**
TOTAL		**26,189,954**	**14,472,767**	**13,760,658**	**11,600,918**	**13,132,852**	**9,839,393**	**14,832,757**

Table 2.11.1: Amounts of dumped dredged material (tons dry weight) per area and country (period 1998–2003) (source: OSPAR annual reports; for the period 1989-1997 see 1999 QSR Table 2.10).

Figure 2.11.1: Amounts of dumped dredged material in the Wadden Sea (tons dry weight) (period 1989 – 2003 (dumping areas see Table 2.11.1). Data source: OSPAR Annual Reports, 1999 QSR. Until 1995 (for NL until 1994), data were reported as tons wet weight; for comparison, the figures before 1995 have been converted to dry weight (wet weight/1.97).



period 1989-1997 when an annual average of 1.9 million t were reported in the 1999 QSR.

In the Fourth National Policy Document on Water Management of 1998, the Dutch government agreed to the development of a new assessment system. With the classic assessment system, the Uniform Content Test (UGT), the content of 33 different contaminations were tested according to specified standards. During period 1998-2002, scientific research was performed to develop an alternative method of testing dredged material. This research resulted in the policy recommendation to switch from the UGT to a so-called Chemical-Toxicity-Test (CTT).

In order to get a better insight into the combined toxic effects of contaminants in dredged material, so-called levels for three sediment bioassays were selected and implemented into the Dutch legislation (Schipper *et al*., 2003; Stronkhorst *et al*., 2003). Since bioassays represent a new element in assessment of dredged material, there is at this stage no representative dataset available to develop quality standards for dumping of dredged material within the Surface Water Contamination Act (Wvo) and Maritime Water Contamination Act (Wvz), in the sense of test values that when they are exceeded leads to disqualification of a particular batch of dredged material. As such, use is still being made of a measurement obligation and signal function for bioassays.

In The Netherlands, all measured contaminant contents, except PAHs, are normalized to a 'standard soil' composition. Sediment quality criteria have been developed for selected heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn), mineral oil (C10-40), sum of 10 PAH compounds, sum of 7 PCBs (PCB 28, 52, 101, 118, 138, 153, 180), HCH-isomers, Heptachlor Heptachlorepoxide, Aldrin, Dieldrin, Endrin, DDT incl. derivates, HCB, TBT; additionally, levels for 3 bio-assays (only valid for the North Sea) were defined (OSPAR Commission, 2004b).

2.11.2 Germany

The highest value of 24 million t were reported in the year 1998. In the following years until 2003, the amounts decreased to values between 7.8-11 million t (dry weight) per year due to a decrease in the Elbe, Jade and Weser areas. The annual average for the period 1998-2003 was with 12.3 million tons lower than for the period 1998-1997 with 22 million tons (dry weight).

In 1999, the 'Directive for dredged material management in Federal Coastal Waterways' entered into force which incorporates the relevant provisions of the latest guidance provided under the London, OSPAR and Helsinki Conventions (HABAK, 1999).

These guidelines are set up for the Federal Waterway and Shipping Administrations and are therefore only applicable to Federal waterways and not to waterways under the responsibility of the federal states. A working group with members of federal and state authorities has been installed to develop common guidelines regarding dumping operations in German coastal waters, estuaries and rivers.

Permits for dredging/dumping of dredged material are issued by the competent authorities of the Federal States ('Länder'). Permits are not issued for dredging/dumping activities of the German Federal Waterway and Shipping Administra-

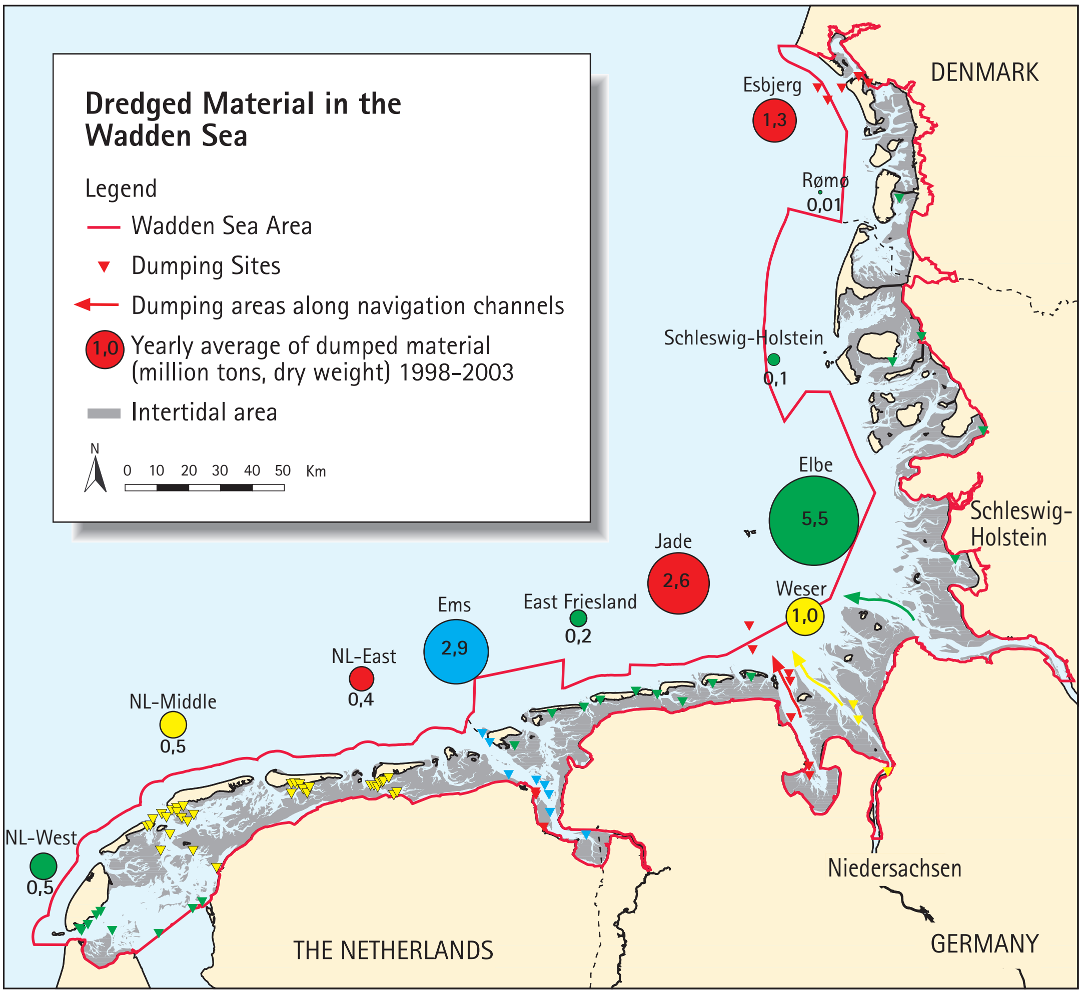


Figure 2.11.2: Map of dumping sites and yearly average amount of dumped dredged material in the Wadden Sea in the period 1998-2003. Data source: OSPAR. Map modified from 1999 QSR.

tions (the responsible Directorate does not issue permits for its own activities). However the dredging/dumping activities of the Federal Waterway and Shipping Administrations are governed by national regulations which are in accordance with OSPAR and London Convention requirements.

Action levels for trace metals and organic contaminants in dredged material applied to dredged material from German federal waterways for trace metals and organic contaminants represent 'management' values. They were introduced in 1992 and 1997, respectively. The action levels are neither ecotoxicological quality criteria nor quality targets. These action levels are not applied to dredged material from waters under the responsibility of the Federal States.

Action levels are related to the sediment fraction < 20 µm, dry weight and exist for selected heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn) and organic compounds (PCB 28, 52, 101, 118, 138, 153, 180, HCHs, HCB, Pentachlorbenzene, Octachlorostyrene, DDT, DDD, DDE, six PAH compounds and mineral oil).

For TBT, action levels were implemented in 2001. They were agreed between the Federal Authorities and the Federal States and are applicable to dredged material from all coastal waterways. The implementation of action levels is tiered in three phases according to the schedule of IMO for the ban of TBT in antifouling coatings of ships, although with a time lag of two years. Action levels for tributyltin (TBT) in dredged material (in µg TBT/kg total sediment) were defined with a lower level of 20 and an upper level of 600.

The upper level decreases from 600 µg TBT/kg in 2001 to 300 µg TBT/kg in 2005 and to 60 µg TBT/kg in 2010.

2.11.3 Denmark

Dredged material dumped in the Danish Wadden Sea mainly originates from maintenance dredging of navigation channels and harbors of Esbjerg (about 0.8-1.8 million t dry weight/yr) and Rømø (about 10,000-31,000 t dry weight/yr) resulting a total annual average of 1.3 million t dry weight for the period 1998-2003.

There are no specific action levels in Denmark, but general principles for dumping of dredged material have been laid down following the guidelines from the London Convention 1972 and the OSPAR Convention.

The guiding principle for dredged material proposed for dumping is that the concentration of heavy metals in the dredged material must not exceed the (local) background value more than twice.

Denmark is currently developing its system for licensing disposal at sea, and the planned approach is to use locally-derived background concentrations. The current view of the EPA is to develop a 3-category system according to the above limits.

The administrative practices are undergoing a thorough revision involving the Parliament. The main cause for this has been the elevated levels of TBT in many harbors.

Revised regulations are expected to be finalized during 2005.

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3. Climate

Albert Oost
Gerd Becker
Jes Fenger
Jacobus Hofstede
Ralf Weisse

(Photo: Nationalparkverwaltung, Wilhelmshaven)

3.1 Introduction

Since there is little difference within the Wadden Sea area in major climatic conditions (de Jong, 1999), the main focus should be on climate change in Northwest Europe and its effects on the Wadden Sea system. The only exception might be local wind climate, a subject which has - until now - received little attention, but which may be important in understanding future coastal and Wadden Sea development. In this chapter we will apply new insights to consider the present-day situation and look forward into this century to form an idea of the changes that may be expected.

3.2 Climate change

3.2.1 Global changes

A few years ago, the Intergovernmental Panel on Climate Change stated that 'Most of observed warming over the last 50 years is likely due to increases in greenhouse gas concentrations due to human activities' (IPCC, 2001). Since the 19th century, average global atmospheric temperature has risen by some 0.6 ± 0.2 °C. For the future, a global average temperature rise of 1.4-5.8 °C by 2100 is predicted, with, however, large local differences. As a result, changes in the rate of global sea level rise between 9 and 88 cm (mean: 48 cm) are expected for the period 1990-2100. Also, storminess will probably increase outside the tropics and waves may become higher. In the northern hemisphere, precipitation at higher and intermediate latitudes has increased during the 20th century by 0.5-1% per decade, coinciding with a probable increase in the number of extreme rainfall events. In the future it is expected that, at intermediate latitudes, the amount of precipitation will continue to increase and will be accompanied by an increase in extremes (Verbeek, 2003).

3.2.2 Local changes in forcing parameters in the Wadden Sea

Temperature of atmosphere and water

Temperature records over the past 120 years show that during the last two decades the air temperatures at the Bilt (The Netherlands) were on average some 0.7 °C higher than in the first two decades (Wessels *et al.*, 2000). In the short term (*i.e.* from year to year), the temperature in the Wadden Sea region depends mainly on the dominant wind direction, but, in the longer term, mainly on global climate development (Verbeek, 2003). It is therefore expected that up to 2100 the air temperature in the Wadden Sea region will increase by on average 2 °C (range: 1-6 °C) (Wessels *et al.*, 2000; IPCC, 2001; Verbeek, 2003). Sea-water temperature is expected to continue to rise similarly since it is closely correlated with the temperature of the atmosphere (Becker and Pauly, 1996; Wessels *et al.*, 2000). It should, however, be noted that serious cooling in Northwest Europe may occur if the North Atlantic Current starts flowing northward at a slower rate due to its own warming and to an increased freshwater influx from the North Pole (Clark *et al.*, 2002; Dickson *et al.*, 2002). Figure 3.1 shows the long-term development of water temperature in the westernmost part of the Wadden Sea, which is a reflection of the west European climatic variability (van Aken, 2003). An overall increase in water temperature has been apparent since about 1980.

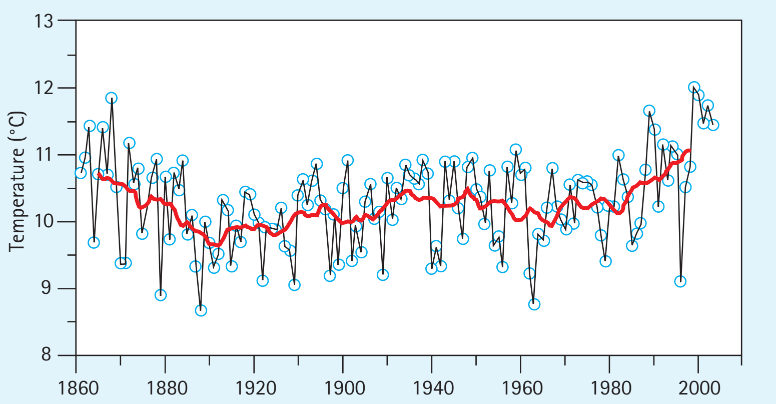

Figure 3.1: Plot of the annual mean sea surface temperature in the Marsdiep tidal inlet from 1861 to 2003. The thick line shows the 10-year running average (Data: Royal Netherlands Institute for Sea Research, Texel, The Netherlands).

Relative sea level

Tide-gauge data indicates a relative sea level rise of a few mm/year during the last century, about half of which is attributed to large-scale subsidence (Töppe, 1993; Dillingh and Heinen, 1994). Also, most stations show a faster rise in Mean High Water (MHW) level than of Mean Low Water (MLW). In The Netherlands, there are no indications of an accelerated rise of MHW, MLW or Mean Sea Level (MSL). In Germany, however, clear accelerations have been observed (Hofstede, 1999a). Töppe (1993) suggests that these changes are the result of long-term cyclic processes rather than of climatic change. The marked differences between the various Danish, German and Dutch measuring stations in the Wadden Sea, however, strongly suggest a dominant role for civil engineering works, such as the dredging of channels (Rakhorst, unpubl.). The rate of relative sea level rise is expected to increase by 10-100 cm/century between 2000 and 2100.

Storminess

Storm activity and the related storm surge and wave conditions in the Wadden Sea show pronounced inter-annual and inter-decadal variability (Figure 3.2). Since *ca.*1960 storm activity in the Northeast Atlantic has increased, but storm activity in the 1990s is comparable to that at the beginning of the last century (WASA, 1998). Alexandersson *et al.* (2000) made an update of the WASA-analysis and showed that in the past few years the storm activity over the Northeast Atlantic and North Sea had decreased. This is in agreement with the decadal fluctuations in storm activity with maxima around 1920, 1950 and 1990 described by Schmidt (2001) and Weisse *et al.*, (2005) for the North Sea. Storm surges and severe wave conditions also show pronounced annual and decadal variations (*e.g.*, Flather *et al.*, 1998; Langenberg *et al.*, 1999; Weisse *et al.*, 2002).

Projections of the expected increase in atmospheric greenhouse gas concentrations indicate a moderate increase in storm activity over the North Sea towards the end of this century. Using different (A2, B2) IPCC SRES emission scenarios (see Houghton *et al.*, 2001), Woth *et al.* (2005) forced a storm surge model for the North Sea with meteorological data sets from various atmosphere models. The results indicate that the largest increase in storm surges is to be expected along the Wadden Sea coast, while changes along the En-

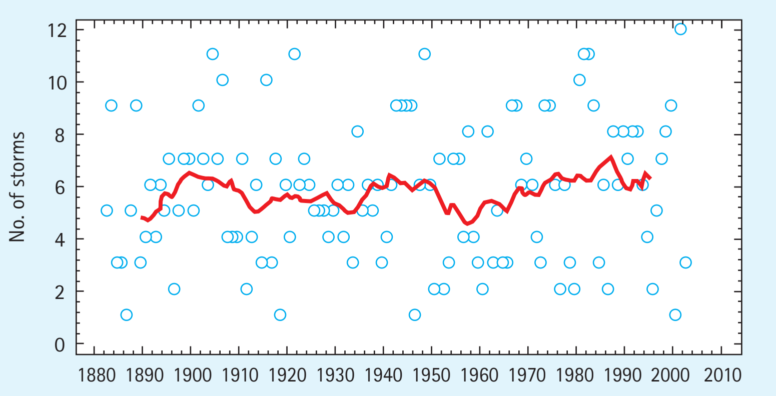

Figure 3.2: Number of times per winter (1 Oct. – 15 March; 1882-2003) that a storm over the North Sea resulted in a water level enhancement >90 cm during high water in Delfzijl, The Netherlands. Red line: 15-year running average (Data: Doekes, RIKZ; Können, 1999).

glish east coast and the Jutland (Denmark) west coast are smaller. This large-scale pattern is consistent with results from earlier studies (*e.g.*, Langenberg *et al.*, 1999; Kaas, 2001).

Precipitation

After the little Ice Age, roughly since 1825, the Wadden Sea climate has become more maritime in character and precipitation has increased, in The Netherlands with 12% between 1900 and 2000 (Können, 1999). For the period 2000-2100 a further increase in precipitation in the winter half year of approx. 12% (range 6-25%) is expected in The Netherlands (Table 3.1). Also for the summer half year the average precipitation is expected to increase by (central estimate) some 2% (range 1-4%). These figures are comparable to those estimated for Germany and Denmark. Extreme precipitation events have gradually increased since the 1970s (Klok, 1998). It is expected that this trend will continue with a 10% increase per degree Celcius (Verbeek, 2003).

Increased precipitation may also lead to increased run-off through rivers to the Wadden Sea. This may result in a further decrease of salinity of the Wadden Sea water (*cf.* Marsdiep tidal inlet; van Aken, 2003).

3.3 Geomorphological and ecological changes

3.3.1 Introduction

The geomorphologic response of the Wadden Sea to the observed and expected changes in forcing factors varies regionally. The same holds for the ecological response, which depends on both the hydraulic and the geomorphological change. Most important are the changes in wave climate and the rate of sea level rise. Locally, changed wind directions, freshwater run-off and precipitation may be important. Below, the combined effects will be presented for the salt marshes, the Wadden Sea proper and the North Sea coast.

3.3.2 Salt marshes

Geomorphology

Higher rates of relative sea level rise (locally enhanced by human-induced subsidence due to extraction of minerals) and higher storm surge frequencies will result in a higher flooding frequency of the salt marshes. This may cause regression of the plant-cover if the vegetation does not trap enough sediment to compensate for, or even outpace, mean high-water rise. Furthermore, erosion will occur when, in the pioneer zone (the border between marshes and tidal flats), sedimentation

	Low estimate	Central estimate	High estimate
Mean precipitation in summer	+ 1 %	+ 2 %	+ 4 %
Mean evaporation in summer	+ 4 %	+ 8 %	+ 16 %
Mean precipitation in winter	+ 6 %	+ 12 %	+ 25 %
Annual maximum for 10-day sum of winter precipitation	+ 10 %	+ 20 %	+ 40 %

Table 3.1: Estimated change in precipitation and evaporation in The Netherlands in 2100 based on three scenarios. From: IPCC (2001) and Verbeek (2003).

is insufficient to compensate for sea level rise, causing formation of cliffs.

An accelerated rate of relative sea level rise of up to 60 cm/century will until 2050 not lead to large problems for the mainland salt marshes if these are bordered by brushwood groynes resulting in sedimentation rates which are higher than sea level rise rates (Oost *et al.*, 1998). Problems will occur for the pioneer zone where sedimentation cannot keep up with sea level rise. At 85 cm/century of sea level rise, it is expected that some mainland salt marshes will start to decay locally. On the barrier islands (at least in the Dutch Wadden Sea) salt-marsh sedimentation rates are lower than on the mainland. Here, it is expected that at a sea level rise of 85 cm/century, regression of the salt marsh vegetation will occur after 2025 (*e.g.*, Dijkema, 1997).

Cliff erosion is already occurring on the salt marshes on the islands and locally on the mainland (*e.g.*, Janssen-Stelder, 2000). Wave heights exceeding 20 cm (during storm surges) result in strong erosion of the marshes and of the mudflats in front (Janssen-Stelder in Brinkman *et al.*, 2001). It is therefore expected that cliff erosion in particular will increase when the rate of sea level rise or of storm frequencies increases (Janssen-Stelder, 2000; Brinkman *et al.*, 2001). Local ef-

(Photo: Nationalparkverwaltung, Wilhelmshaven)

fects will be strongly dependent on local measures taken to protect the marshes.

Observations in England showed that a considerable lowering of the intertidal mudflats was caused by an increase in extreme precipitation (K. Dyer, pers. com.). If this applies to the Wadden Sea, this would be another factor causing cliff formation.

Ecology

Increased cliff erosion due to changed storm conditions and accelerated sea level rise will decrease the area of salt marshes, and therefore cause loss of habitat for birds such as Brent geese (Ens in Brinkman *et al.*, 2001). On the other hand, rapid relative sea level rise will slow down the rapid vertical accretion of tidal marshes with respect to sea level, thus resulting in a slower loss of rare salt marsh species (Oost *et al.*, 1998).

3.3.3 The Tidal Area

Geomorphology

The various geomorphological features of the Wadden Sea, such as outer deltas, barrier islands, tidal flats and channels, are in most cases in a dynamic equilibrium with the prevailing current and wave conditions. This is caused by the continuous transport and redistribution of sediment. At a constant rate of sea level rise, a tidal inlet system will import sediment.

The tidal inlet system is expected to compensate for changes in the rate of sea level rise up to a critical limit (see Table 3.2). A possible exception is the Lister Tief inlet which is either eroding or not yet in equilibrium (Wang and van der Weck, 2002). The precise critical limit for the rate of sea level rise that can still be compensated for by sedimentation depends in part. on the size of the tidal basin. The larger the basin the lower the critical limit (Oost *et al.*, 1998; Stive *et al.,* 1998; van Goor *et al.*, 2001; Kragtwijk, 2001). In the Dutch Wadden Sea, assuming the present wave conditions, this critical limit is thought to be 30 cm/century for large tidal basins and 60 cm/century for small tidal basins. Above this limit the tidal flats will 'drown'.

The effects of sea level rise up to 2050 are rather limited. Models predict a relative lowering of the intertidal flats of maximally 20 cm. Locally, subsidence due to extraction of minerals may result in an additional lowering of 15 cm.

There has been little study of the effects of changes in storminess and wave-action in the back barrier area (Hofstede, 1999b). An increase in storm frequency might result in a lowering of the tidal flats (cf. Jansen-Stelder, 2001), possibly enhanced by the concomitant destruction of seagrass areas and mussel banks. Surprisingly, however, model studies by van Goor (2001) show that the probability of tidal flats drowning will decrease with increasing storminess. This is due to increased sand imports from the North Sea coasts of the barrier islands. If correct, and combined with the above observation by Jansen-Stelder (in Brinkman *et al.*, 2001), this may lead to the development of more pronounced inner deltas, while the more landward parts of tidal flats may become deeper. Another effect of stronger wave-action will probably be increased channel dynamics, especially in the outer deltas and near the inlets.

Ecology

Climate change may change the ecosystems in the Wadden Sea, the adjacent North Sea zone and on the mainland. These changes are expected to be minor until 2050. An increase in temperature may lead to changes in species composition, due to species adapted to a cooler environment retreating northward, whereas new species from southern areas will appear.

Climate change may lead to a range of ecological effects, such as an increase in viral infection (*cf.* Brussaard *et al.*, 1999; Harvell *et al.*, 1999; Mulder and Peperzak, 2003), and a faster growth of bacteria causing faster mineralization of organic matter (Mulder and Peperzak, 2003). The phytoplankton species composition may change as a result of increasing temperatures and changes in the nutrient supply (L. Peperzak, pers. com.; Peeters *et al.*, 1999). Increased occurrence of algal blooms may cause problems because of their toxicity (*e.g.* dinoflagellates) and accompanying oxygen deficiency (*e.g.*, Peperzak, 2003). It is not known whether the growth rate of zooplankton species will increase or decrease due to climate change (Peperzak, 2003). Climatic changes in the north Atlantic area and changes in position of the North Atlantic Current are thought to have already caused shifts in zooplanktic copepod assemblages in European coastal waters (Beaugrand *et al.*, 2002; Frid and Huliselan, 1996).

Lowering of the tidal flats in the Wadden Sea is expected to lead to a decrease in zoobenthic biomass (Beukema, 2002). An increased stormi-

Table 3.2: Loss of relative height of tidal flats (in cm) according to various sea level rise (SLR) scenarios (Oost, in prep.).

	Expected loss of relative height (cm) of tidal flats in 2050	
SLR scenario	**Minimum**	**Maximum**
18 cm/century	0	0
60 cm/century	0	11
85 cm/century	5	18

ness may lead to a decrease of epibenthic species such as oysters, blue mussels and seagrass. Changes in the discharge of fresh water will probably only have local effects. Milder winters will affect the reproductive success of bivalves and probably lead to reduced stocks (see chapter 8.2 Macrozoobenthos).

The Wadden Sea area is important as a nursery and a migration route for many fish species. Temperature changes may have a significant impact, for example, on growth (Wanink, 1999), also changing the species composition of fish (*cf.* Atrill and Power, 2002).

Bird numbers, and species composition, may change 10% or more until 2050, due, for example, to changes in food availability (decrease in tidal flat benthos) and loss of roosting sites (due to erosion), this being dependent on the rate of loss of intertidal area by drowning. Milder winters, on the other hand, may be beneficial for birds since their energy uptake requirement will be smaller (Moss, 1998; Mulder and Peperzak, 2003).

For the common seal, suitable haul-out places may decrease in number, possibly affecting its reproduction success in the Wadden Sea, and causing the population to decrease. Higher temperatures may cause enhanced occurrence of viral infections (Harvell *et al.*, 1999).

3.3.4 Beaches and dunes

Geomorphology

Under conditions of sea level rise and changing wave climate, the reinforced coasts (dikes, tetrapods) will not change much. Sandy coasts, however, will change.

In the long term, the position of the North Sea sandy coast is determined by the balance between sand supply from the North Sea and transport of sand from the coast into the Wadden Sea. Sand supply from the North Sea is limited (van der Molen and Swart, 2001; van der Molen, 2002). The transport of sand to the Wadden Sea via the inlets and wash-overs may thus result in coastal erosion. Accelerated sea level rise, increasing the sand demand in the back barrier areas, will result in a retreat of the North Sea coasts through faster erosion and faster flooding of the coasts (Mulder, 2002). Locally, however, exceptions occur. At present, the west coast of the island of Sylt is retreating as a result of sea level rise. The eroded sediments drift to the north and to the south and probably partly accumulate on the beaches of Rømø and Amrum. As a result, the coastlines of the latter two islands are stable, or even accreting, despite the observed sea level rise.

It can be calculated that the rate of coastal retreat can increase up to a long-term average of about 8 m/yr, *i.e.* until the critical upper boundary of the rate of sea level rise above which tidal flats start to drown. It is estimated that for a sea level rise scenario of 60 cm/century, the total sand demand and sea level rise may result in a coastal retreat up to 3 times faster than at present, and up to 3.5 times more rapid in the case of a sea level rise of 95 cm/century. Such retreats, however, can and probably will largely be counteracted by sand nourishment of beaches or foreshores, thus preserving the characteristic sandy coast dynamics of the Wadden Sea coasts.

More frequently occurring storm surges tend to make the coast more dissipative, resulting in flat beaches. Calculations indicate that the already quite dissipative character of the Dutch Wadden Sea coast is not very likely to change much.

A higher storm surge frequency and higher water levels will also influence the unprotected parts of barrier islands, either via wash-overs or via flooding of the backbarrier side. For several areas above MHW-level it has been observed that wash-over and spit-formation may help to keep up with sea level rise while retreating in a landward direction (Hofstede, 1999a). An increase in sea level will also result in stronger erosion of the dunes. The exact rates of such erosion are not yet known. If dunes are to protect inhabited areas, more work will be needed to maintain them at higher rates of sea level rise.

Changes in wind- and thus wave climate may result in increased dynamics for the coasts and ebb-tidal deltas. An increase in storm activity has resulted in a retreat and decrease in sand volume of the ebb-tidal delta of the Hörnum inlet (German Wadden Sea) since 1960 (Hofstede, 1999a). This is in contrast with a possible increase in tidal volume in the backbarrier area if sea level rise cannot be fully compensated by sedimentation, resulting in a larger sand volume of the ebb-tidal delta. It is unclear which effect will dominate in the future.

Ecology

On the barrier islands an increase in sea level may lead to higher groundwater tables, resulting in vegetation changes in the lower dune valleys and a possible enhancement of peat growth. Also, salinity gradients may change, resulting locally in a shift in distribution of plant and animal (mainly invertebrates) species. More frequent flooding may also lead to eutrophication and calcification of the soil, leading to a decrease of species having a preference for poor soil conditions such as orchids and lichens (Ketner-Oostra and van der Loo, 1998).

3.4 Conclusions

Climate changes in the Wadden Sea area are mainly related to large-scale (*e.g.* Northwest European) changes in climate. The precise response of the Wadden Sea system, however, depends to a large extent on local conditions and configuration of the tidal basins.

Changing rates of sea level rise, a changing river discharge and changes in the storminess and wave-action may change the geomorphology of the Wadden Sea area. In the Dutch basins and probably also in most of the others too tidal flats are expected to be able to keep up with sea level rise due to faster sedimentation up to a critical limit of sea level rise of 3 mm/yr (for large tidal basins) to 6 mm/yr (for small basins). For salt marshes, this critical limit is at least 8.5 mm/yr, and for the pioneer zone 3-6 mm/yr. Above the critical limit flats and marshes will 'drown'. The increasing sediment demand in the tidal basins will trigger a faster erosion of the sandy North Sea coasts. Combined with the direct effect of a rising water level, it is estimated that the total coastal erosion will increase to 250% of the present level of 6 mm/yr and to 330% at 8.5 mm/yr. This can be compensated for by nourishments.

Effects of changes in temperature, in hydrodynamic regime and in geomorphology on the ecology of the coastal zone are expected to be minor up to 2050, with the exception of the possibility of more frequently occurring toxic algae blooms. Possible effects are a shift in species composition, changed growth rates, a decrease in benthos biomass and of benthos consuming birds (in case of lowering of the tidal flats), and the risk of increased viral infections.

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4. Hazardous Substances

Joop F. Bakker
Martine van den Heuvel-Greve
Dick Vethaak
Kees Camphuysen
David M. Fleet
Bettina Reineking
Henrik Skov
Peter H. Becker
Jacqueline Muñoz Cifuentes

Figure 4.1.1: Map of the Wadden Sea with subareas used for evaluation and assessment of hazardous substances.

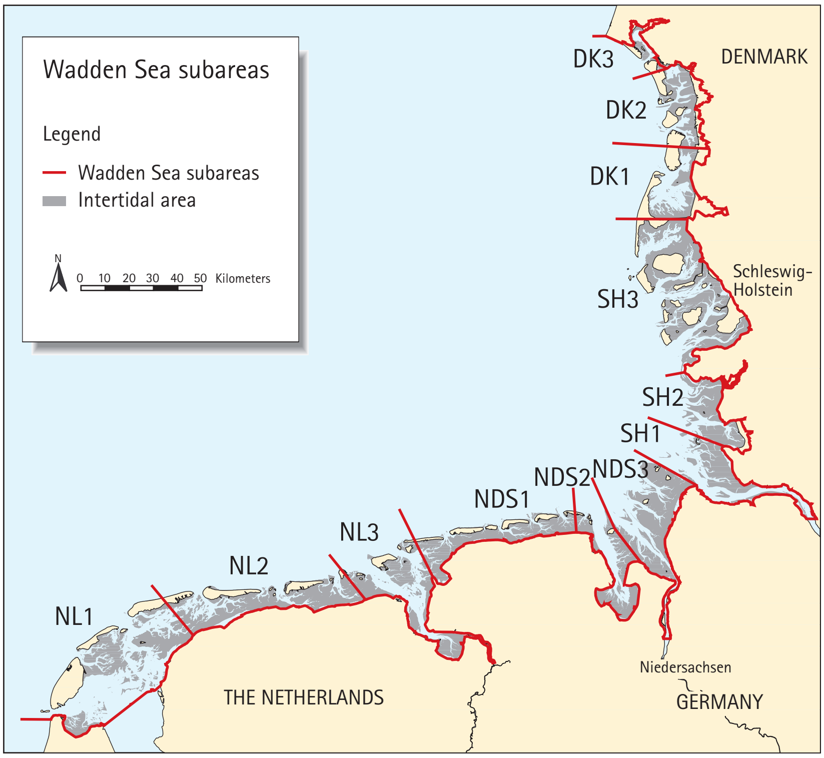


Table 4.1.1: QSR coding and description of the Wadden Sea subareas.

	QSR Subarea Description
NL1	Western Dutch Wadden Sea. The area receives fresh water directly from Lake IJsselmeer by the sluices of Den Oever and Kornwerderzand at an average rate of 16.3·10⁹ m³/y. The water mass which originates from the river Rhine passes Lake IJsselmeer in about 50 days. The coastal North Sea water entering the Wadden Sea at the Marsdiep constitutes about 15% Rhine water.
NL2	Eastern Dutch Wadden Sea. The area receives a minor freshwater source from Lake Lauwers and an industrial waste line. The area is considered to be dominated by coastal North Sea water.
NL3	Ems-Dollard estuary. The freshwater sources to the area are the river Ems (90%) and Westerwoldsche Aa (10%) at a total average rate of about 3.4·10⁹ m³/y. Industrial and harbour activities border the estuary at Emden, Delfzijl and Eemshaven.
NDS1	Niedersachsen Wadden Sea. The area is slightly influenced by local fresh water sources. Only small harbours are present. The area is considered to be dominated by coastal North Sea water.
NDS2	Jade Basin. The harbour of Wilhelmshaven is the main activity in the area. Virtually no fresh water enters the area. The area is considered to be dominated by coastal North Sea water, which becomes enriched by sediment efflux of components during high tide.
NDS3	Weser estuary. The river Weser is the main freshwater source at an average rate of 11.3·10⁹ m³/y. The river borders are densely populated. Harbour activities are present at the cities of Bremen and Bremerhaven.
SH1	Elbe estuary. The river Elbe is the main freshwater input into the area at an average rate of 24.5·10⁹ m³/y, which is about 43% of the total freshwater input in the international Wadden Sea. The river is bordered by large cities (*e.g.* Hamburg), harbours and industrial activities.
SH2	Eider estuary. The river Eider constitutes a relatively small freshwater source of about 0.9·10⁹ m³/y on average. The population density is moderate. Some small recreational and fisheries harbours are present.
SH3	Halligen. Virtually no freshwater input and a low population density. The area is considered to be dominated by coastal North Sea water.
DK1	Sylt-Rømø basin. The area is physically bordered by the dams connecting Sylt and Rømø to the mainland. The area is considered to be dominated by coastal North Sea water. The freshwater input from southern Jutland was about 0.8·10⁹ m³/y in 1990, which was about 1.3·10⁹ m³/y to DK1 + DK2 in the same year.
DK2	Ribe and Konge Å estuary (Knudedyb), Rejsby and Brøns Å (Juvredyb). The rivers Ribe, Konge, Rejsby and Brøns Å are small rivers, thus constituting a small freshwater input. The input to DK1 + DK2 is about 1.2·10⁹ m³/y on average. The area is considered to be dominated by coastal North Sea water.
DK3	Varde and Sneum Å estuary (Grådyb). The last natural estuary of the Wadden Sea. The city of Esbjerg is the main center of population and harbour and industrial activity. The area is considered to be dominated by coastal North Sea water.

4.1 Introduction

Joop F. Bakker
Martine van den Heuvel-Greve
Dick Vethaak

4.1.1 Data sources

Riverine inputs of hazardous substances were mainly extracted from annual reports by OSPAR, and augmented with information from national OSPAR contact points. Atmospheric inputs were available only for the Dutch Wadden Sea.

Information about reallocation of dredged material and its content of hazardous substances was taken from OSPAR (2003). Concentrations of metals and organic compounds in sediment and biota were taken from the TMAP data units, the 1999 QSR database at RIKZ Haren and from other national data centers or data originators.

4.1.2 Assessment procedure

In the assessment procedure a contaminant was followed from its riverine source to the accumulation in sediment and biota. The data was evaluated visually for temporal and spatial trends over the period 1985-2002/03. The actual concentrations were compared with background and ecotoxicological assessment criteria, as accepted by OSPAR (1997). Before data evaluation, harmonized parameterisation was checked and quality control of data performed.

The results of all assessments are summarized at the end of each paragraph. Similarity in trends was not checked for (cor)relation, for example between input and concentration in sediments.

For the purpose of the assessment, the Wadden Sea was divided into 12 subareas consistent with the QSRs of 1993 and 1999 (Figure 4.1.1). Some of the areas are of an estuarine nature due to riverine water input. Subareas will be referred to by their QSR code as shown in Table 4.1.1.

4.2 Natural Contaminants

Joop F. Bakker
Martine van den Heuvel-Greve
Dick Vethaak

4.2.1 Introduction

The entire Wadden Sea is covered by both the OSPAR agreements on chemical compounds and the EC Water Framework Directive (WFD). OSPAR agreements cover the entire North Atlantic and bordering seas; the delimitation of the WFD extends to the 12 nautical miles territorial boundary for priority compounds.

In the WFD, some metals and natural organic micropollutants are proposed as priority compound quality standard and assessment is based on annually averaged total concentrations in water. The Expert Group on Analysis and Monitoring of Priority Substances (AMPS) is presently looking for a suitable sediment monitoring program within the WFD. OSPAR (2002) decided on a 'List of Chemicals for Priority Action'. Copper and zinc are not included in the preliminary WFD and OSPAR lists, whereas nickel and organic tin are a new focus of attention. Nickel could not be included in this QSR due to data not being available for all Wadden Sea subareas.

The 1999 QSR summarized that, in general, riverine inputs and concentrations in sediment and biota of metals had decreased with the exception of mercury concentrations. Some hot spots, however, could be identified, for example, for mercury in sediment and blue mussels. Here, concentrations were higher than the background levels or ecotoxicological assessment criteria proposed by OSPAR. A detailed summary of the 1999 QSR results is given below for each compound evaluated.

Target

Background concentrations of natural micropollutants in water, sediment and indicator species

4.2.2 Metals (Cd, Cu, Hg, Pb, Zn)

4.2.2.1 Data

Riverine input data is available as yearly submissions to OSPAR. Denmark does not report metals to OSPAR. Data for polycyclic aromatic hydrocarbons (PAHs) is not reported to OSPAR and so is not readily available.

Due to the large differences in both annual and river flow, the riverine metal loads into the Wad-

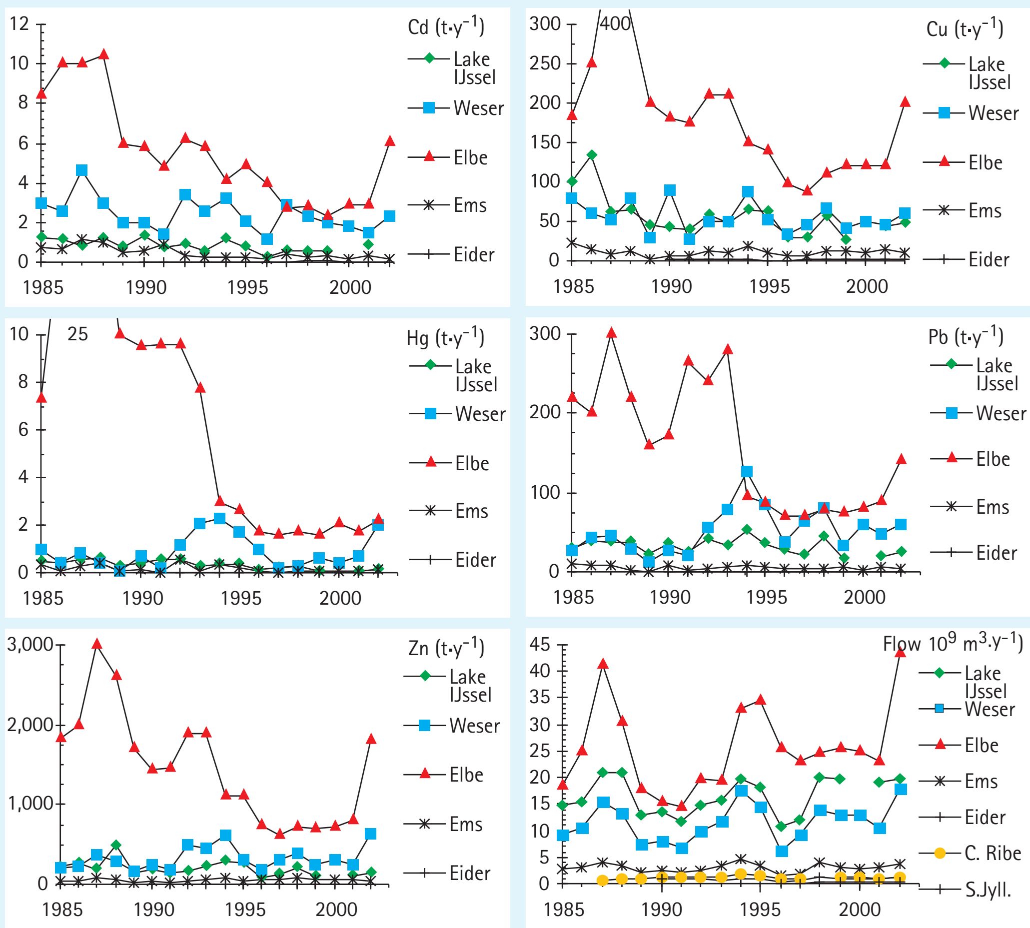


Figure 4.2.1: OSPAR reported fluvial metal input (ton·yr^{-1}) into the Wadden Sea. Flow rate is shown for comparison (sources: D: Umweltbundesamt; NL: Rijkswaterstaat).

den and North Sea vary profoundly (Figure 4.2.1). To reduce this variability, riverine loads were recalculated to a 'standard' flow rate of 10^9 m^3 y^{-1} (Figure 4.2.2) which can also be used in terms of yearly-averaged concentration in river water (ton 10^{-9} m^{-3}).

Data on atmospheric input originate from published data and model calculations.

Disposal of dredged material from estuarine harbors is a displacement of deposited mainly marine suspended particulate matter (SPM) to which many chemical compounds adhere. The physical impact by volume and the trend in contaminant levels may be considered as quality criteria for the aquatic environment (OSPAR, 2003). Trends in dredged material concentrations in the Elbe estuary are shown as an example.

Intercomparison of monitoring data for metals in sediment is still hampered by different methods used in monitoring, sample preparation and analyses (*ref.* 1999 QSR). To partly overcome this problem, the correction procedure of Koopmann *et al.* (1993) was applied to achieve intercomparability between data obtained from <20 µm and <63 µm sediment grain size fractions.

Alternatively, standardization to 1% Total Organic Carbon (TOC) was introduced by Cato, 1977 and Johannesson *et al.*, 2003. Though this method is not sensitive for differences in grain size, it is, however, quite sensitive to the accuracy of TOC measurements, especially in the lower TOC range ($\leq$ 0.5%). For intercomparison purposes, the metal/aluminium ratio proposed by OSPAR (1997, 2002) could not be applied due to still existing differences in sediment destruction methods (*ref.* 1999 QSR).

All data for metal concentrations in blue mussel (*Mytilus edulis*) and flounder (*Platichthys flesus*) were recalculated to dry, homogenized tissue weight.

4.2.2.2 Cadmium

Input

All rivers showed a continuing decrease in cadmium loads, taking into account flow and precipitation rate related variations (Figure 4.2.1). Elbe and Weser generally return a factor of 4 higher than Lake IJssel, Ems and Eider, both in load and year-averaged concentration. The high river flows of

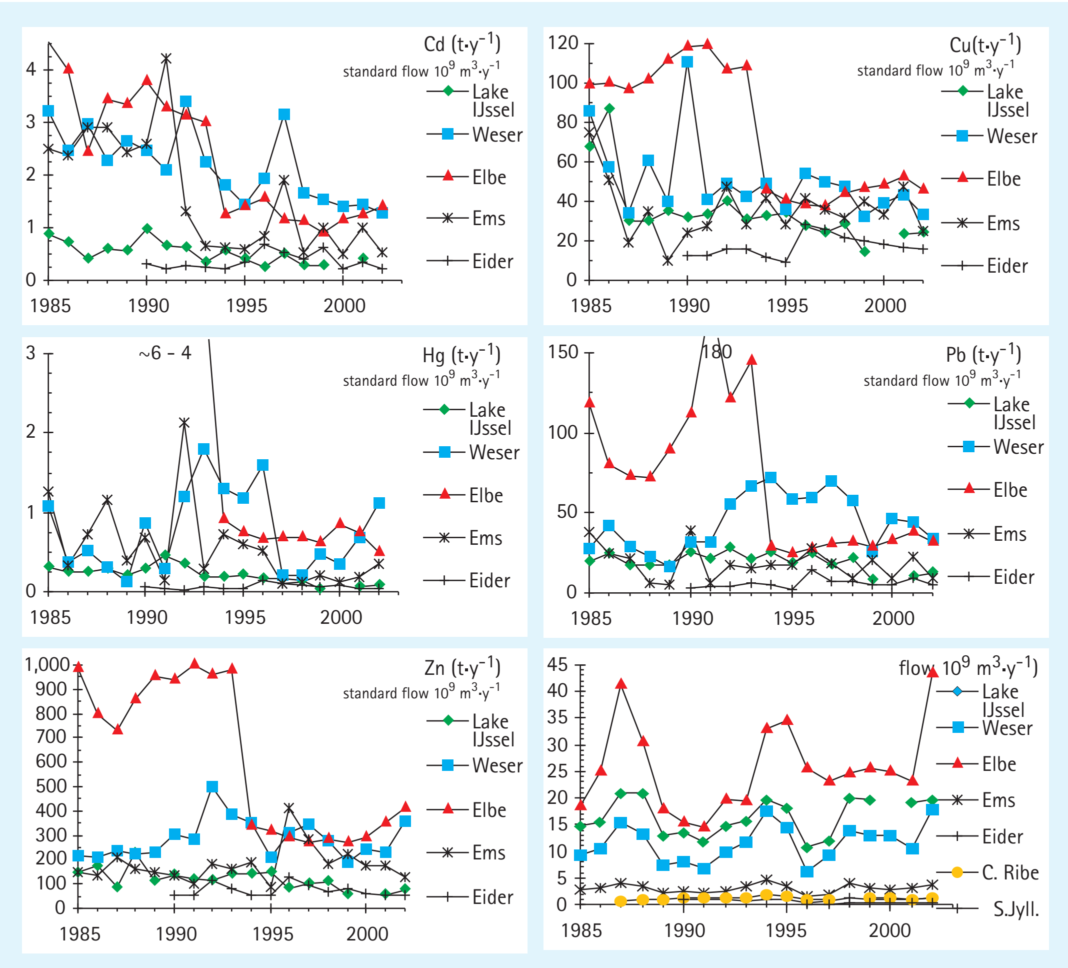


Figure 4.2.2: OSPAR reported fluvial metal input into the Wadden Sea. All fluxes (ton·y^{-1}) have been recalculated to a standard flow of 10^9 m^3·y^{-1}. Year-averaged water concentrations follow the same trend. The real river flows are added for comparison (sources: D: Umweltbundesamt; NL: Rijkswaterstaat).

QSR 1999 (period 1985-1996)

A strong input reduction of 50-75% was concluded for Lake IJssel, Ems and Elbe, extending to a reduction of concentrations in sediments and blue mussel (for the Elbe estuary). Concentrations are within, but at the high end of the range of background values and ecotoxicological assessment criteria.

2002 (comparable to 1987) caused a relative increase in cadmium input. The Elbe flooding of 2002 does not show up in the cadmium data.

Atmospheric input of 158 kg y^{-1} is about 3% of the total riverine input (5,520 kg y^{-1}) (Table 4.2.1).

Table 4.2.1: Atmospheric metal input into the Dutch Wadden Sea in 2001 as modelled and calculated from ground stations (source: Bleeker and Duyzer, 2003).

Compound	Metal input Dutch Wadden Sea 2001 (kg y^{-1})
Cadmium	158
Copper	3,934
Mercury	39
Nickel	3,021
Lead	6,984
Zinc	16,337

Concentrations in dredged material and sediment

During 1988-2002, the year-averaged cadmium concentrations in dredged material from the Elbe estuary showed a continuous decrease (Figure 4.2.3). This reduction is consistent with the decrease in riverine input and concentrations in sediments

In the south-western Wadden Sea subareas (NL1 to NDS3) sediment cadmium concentrations decreased significantly as early as the first half of the 1990s, and this trend continued until 2002 (Figure 4.2.4). The north-eastern subareas (SH1 to DK2) do not show this trend, because cadmium levels there have always been relatively low. For DK3 no data was available.

In the Dutch Wadden Sea, Ems-Dollard (NL1-NL3) and Halligen (SH3) subareas, the cadmium content of the sediment is 2-3 times higher than elsewhere in the Wadden Sea, where cadmium concentrations are at or below the background (Pachur *et al.*,1995). Everywhere in the Wadden Sea, the reported cadmium levels are within the range of the provisional ecotoxicological assessment criterion (OSPAR, 2004) (Table 4.2.3).

Concentrations in blue mussel

Temporal trends are obscured by highly variable concentrations in mussel tissue (Figure 4.2.5). Considering the average values, cadmium levels in SH1 decreased between 1994 and 1997, which would be consistent with the decreasing trend in Elbe input. The longer data series show in the same trend for the periods 1985-1996 and 1996-2002.

Geographical differences in mussel cadmium levels, with concentrations in NL3, NDS3, SH1, DK1 to DK3 being about twice as high as in NL1, NL2, NDS1, NDS2 and SH3 would be consistent with the lower cadmium concentrations in Lake IJssel and River Eider. Levels in NDS3, possibly coinciding with the higher Weser concentrations, and in DK1 are amongst the highest. Here the proposed background (OSPAR, 1997, 2002; assuming 85% water in wet weight) is exceeded by a factor of 2-3.

Concentrations in flounder

As for blue mussels, the high variability of cadmium levels in flounder livers complicates the detection of temporal trends (Figure 4.2.6). This variability can be partly attributed to inconsistent age composition of samples and age dependent accumulation.

In subarea NL1, a decreasing frequency of high maxima suggests a temporal trend of decreasing cadmium levels. In contrast, subareas NDS1 and SH1 may show an increasing trend as from 1996. In SH1 the sudden increase of high values in 2002 and 2003 may be the consequence of the 2002 Elbe flood.

Subarea SH1 shows the highest levels, which cannot be cross-checked with blue mussels, due to missing data for the period 1998-2002. Levels in NL3, NDS1, NDS3 and DK3 are about half of those in SH1. Levels in NL1 and NDS2 are at about a quarter of those in SH1. Except for subarea NDS1, this picture is consistent with the data on blue mussels. Mobilization of residual cadmium in the Elbe estuary may be the cause of the elevated levels in flounder, which migrate between marine and fresh water.

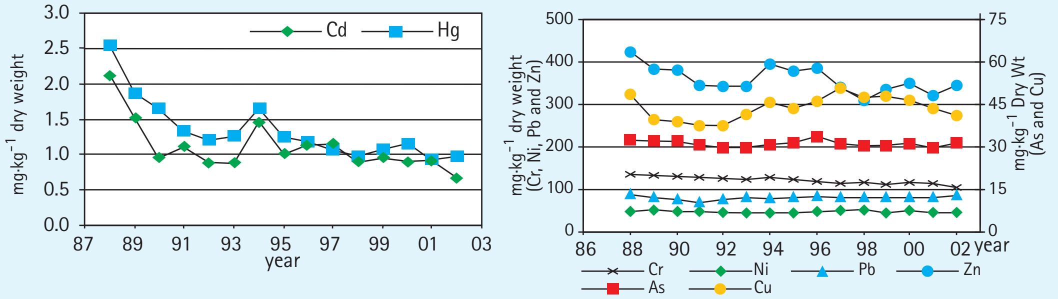


Figure 4.2.3: Trends in year-averaged metal concentrations in Elbe estuary dredged material (mg kg^{-1} dry weight, sediment fraction <20 µm) disposed of at sea (source: OSPAR, 2003).

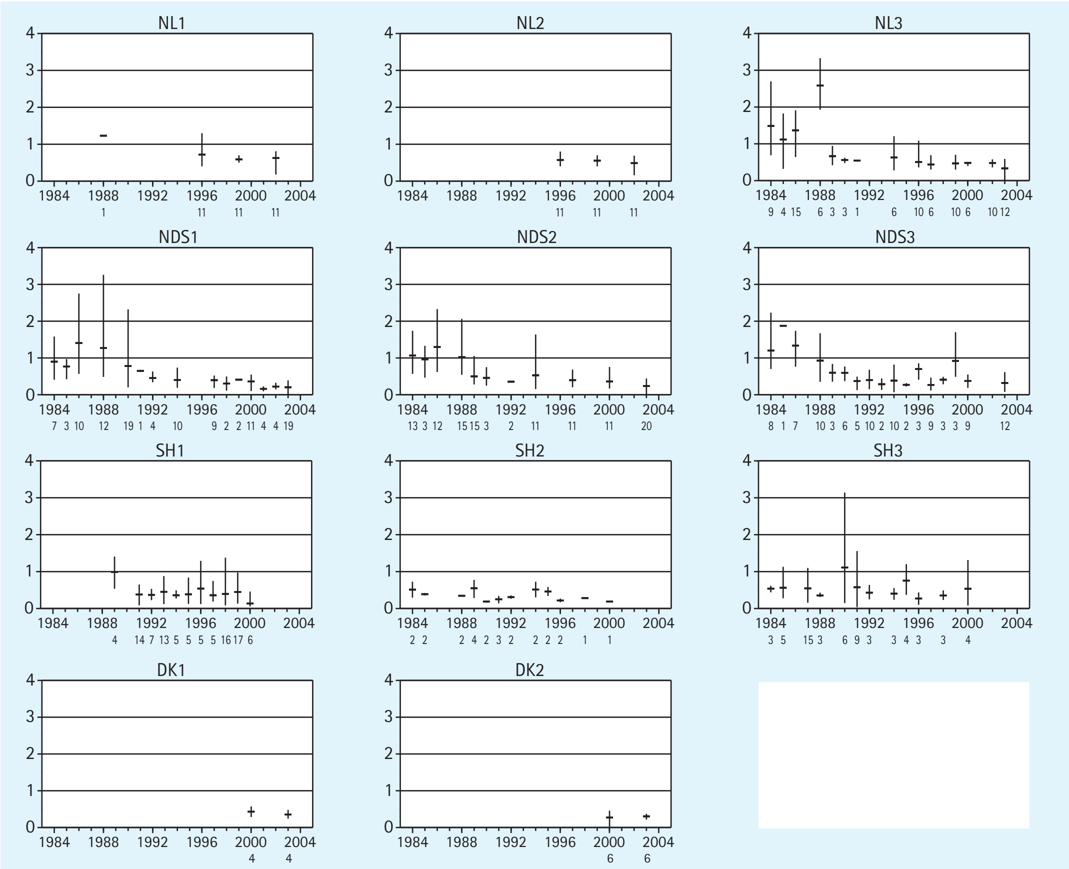


Figure 4.2.4: Cadmium (Cd) contents in Wadden Sea sediments (mg·kg^{-1} dry weight in the fraction <63 µm). Average (–) and minimum/ maximum range (|) is shown.

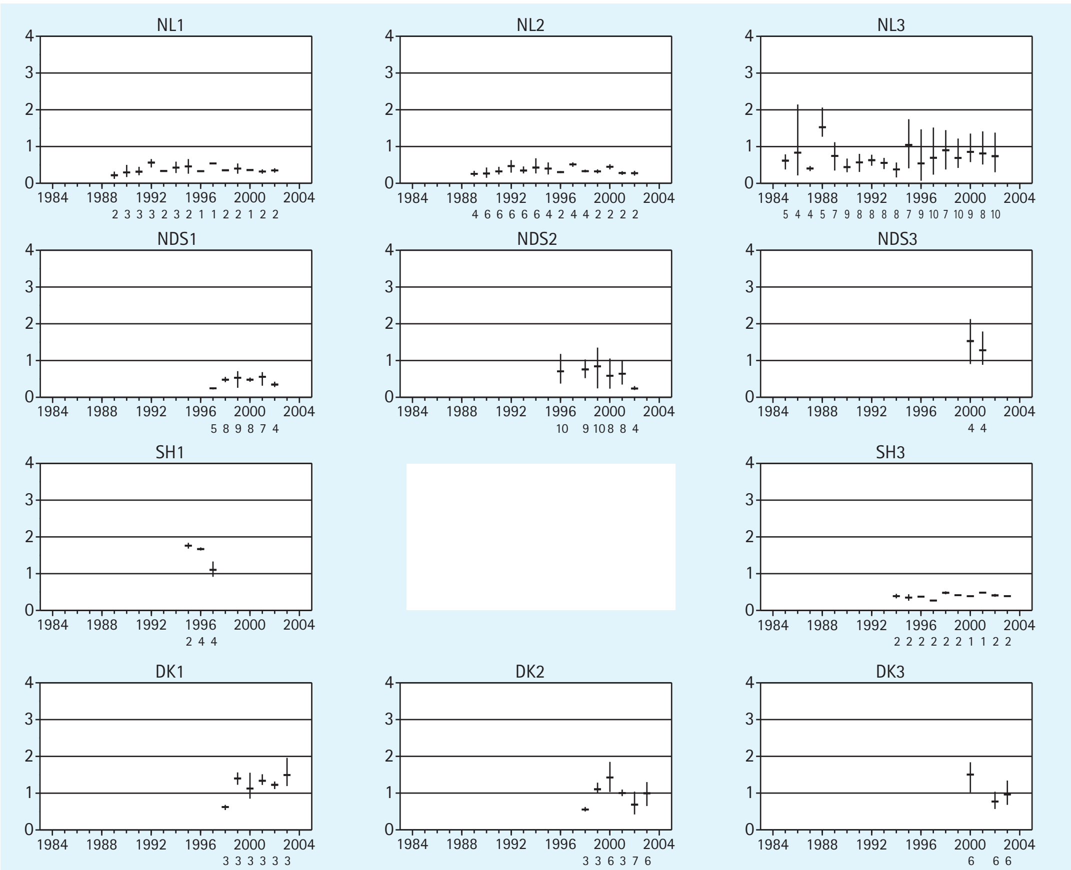


Figure 4.2.5: Cadmium (Cd) contents in Wadden Sea blue mussel *Mytilus edulis* (mg·kg^{-1} dry weight). Average (–) and minimum/maximum range (|) is shown.

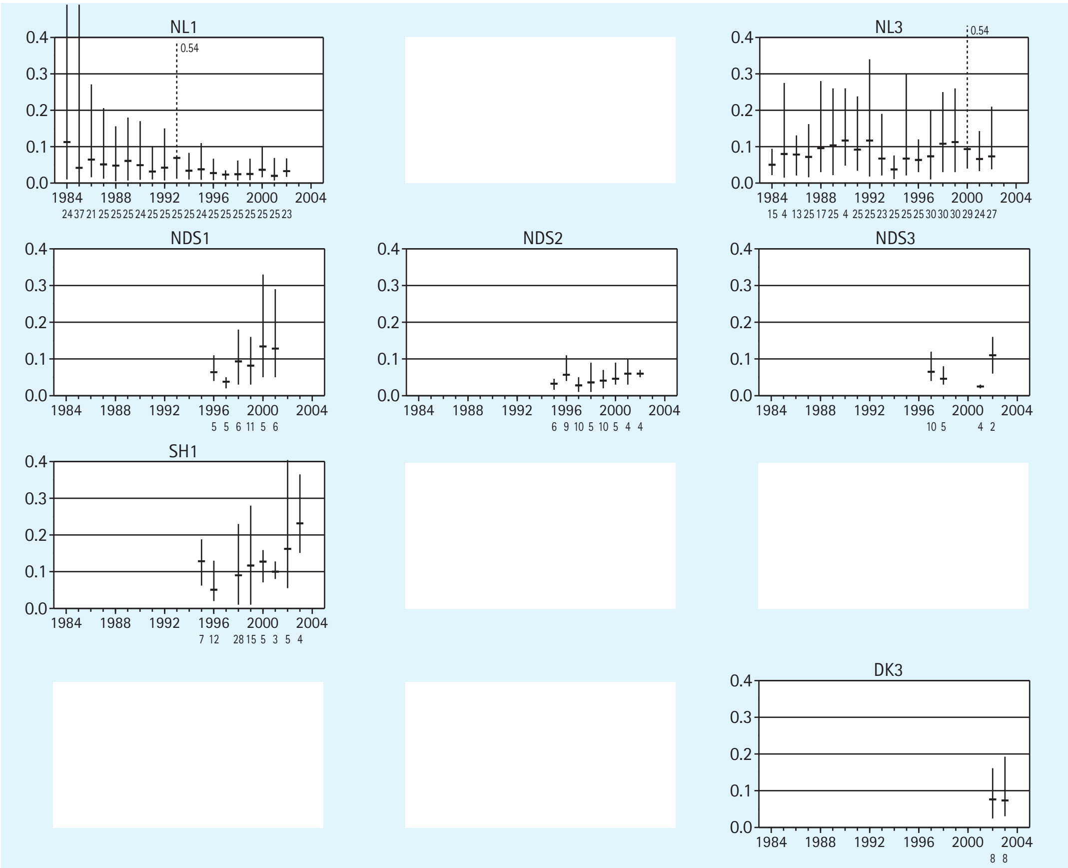


Figure 4.2.6: Cadmium (Cd) contents in liver of Wadden Sea flounder *Platichthys flesus* (mg·kg^{-1} dry weight). Average (—) and minimum/ maximum range (|) is shown.

4.2.2.3 Copper

Input

The concentrations of copper in the Elbe remained at the reduced level of 1994

Year-averaged concentrations show a decreasing gradient from Elbe, Weser, Ems, Lake IJssel to Eider, where the Elbe has twice the Eider concentration. The reduction in riverine loads has been marginal since 1989, except for the Elbe, with a highly increased load in 2002 (Figure 4.2.1).

The actual riverine input is strongly related to river flow and thus precipitation. This implies that a period of reduction in water concentration, coinciding with an increasing riverine flow, covers up strong reductions. This situation occurred in Lake IJssel, the Ems and Weser between 1985 until 1987.

QSR 1999

The Elbe showed a significant reduction in input between 1993 and 1994. In the Ems and Eider areas a reduction of copper concentration in blue mussels was apparent, which correlated with a riverine water concentration rather than with the load.

Copper concentrations were largely at the agreed background in sediment and mussels (except for the Elbe) and within the range of ecotoxicological assessment criteria (OSPAR, 1997).

The atmospheric input (Table 4.2.1) to the Dutch Wadden Sea area is about 2% of the total riverine input to that area (Bellert *et al.*, 2004).

Concentrations in sediment

The copper concentrations in sediment vary greatly (Figure 4.2.7). The standardized concentrations (in the <63 µm fraction), however, show a stabilized level for most Wadden Sea subareas in the last decennium. Most concentrations are at the proposed background levels. Relatively high levels were found in DK2, DK1 and NL1, surpassing the Wadden Sea background level of 10.3 µg·kg^{-1} (*ref.* 1999 QSR).

Anomalous levels were found in SH3 and DK2 in sediments with less than 0.5% TOC (Figure 4.2.8). In DK2, levels elevated by a factor of 5-6 were found at one, probably sandy location with a very low TOC content. In SH3, levels elevated by a factor of 2-3 were recorded. This might indicate analytical limitations in sediments of such low TOC contents, but also local contamination or cross-contamination of the sample. The observed anomaly in relation to low TOC did not apply to lead or zinc levels.

In all subareas, copper levels were within the range of the provisional ecotoxicological assess-

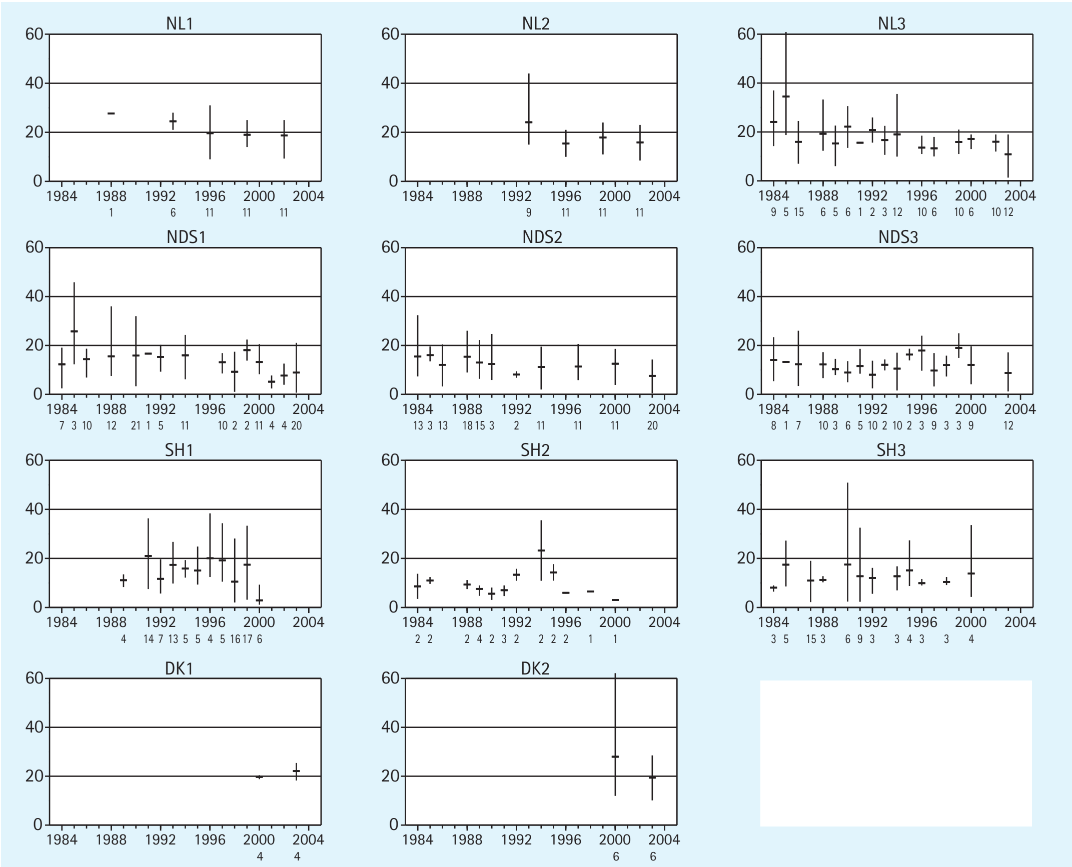


Figure 4.2.7: Copper (Cu) contents in Wadden Sea sediments (mg·kg^{-1} dry weight in the fraction <63 µm). Average (–) and minimum/ maximum range (|) is shown.

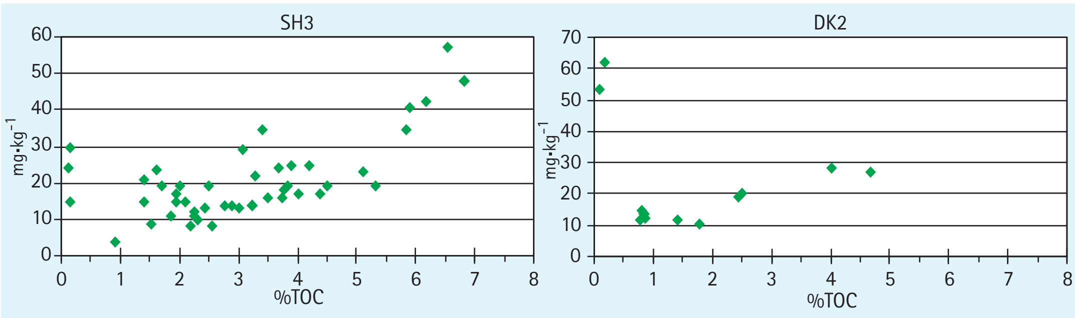


Figure 4.2.8: Copper (Cu) contents in Wadden Sea sediments from SH3 (mg·kg^{-1} dry weight in the fraction <20 µm) and DK2 (mg·kg^{-1} dry weightin the fraction <63 µm) as function of total organic carbon content (%TOC). All available data from 1984 – 2003. For anomalous high concentrations at low (DK2) and high (SH3) organic carbon content see text.

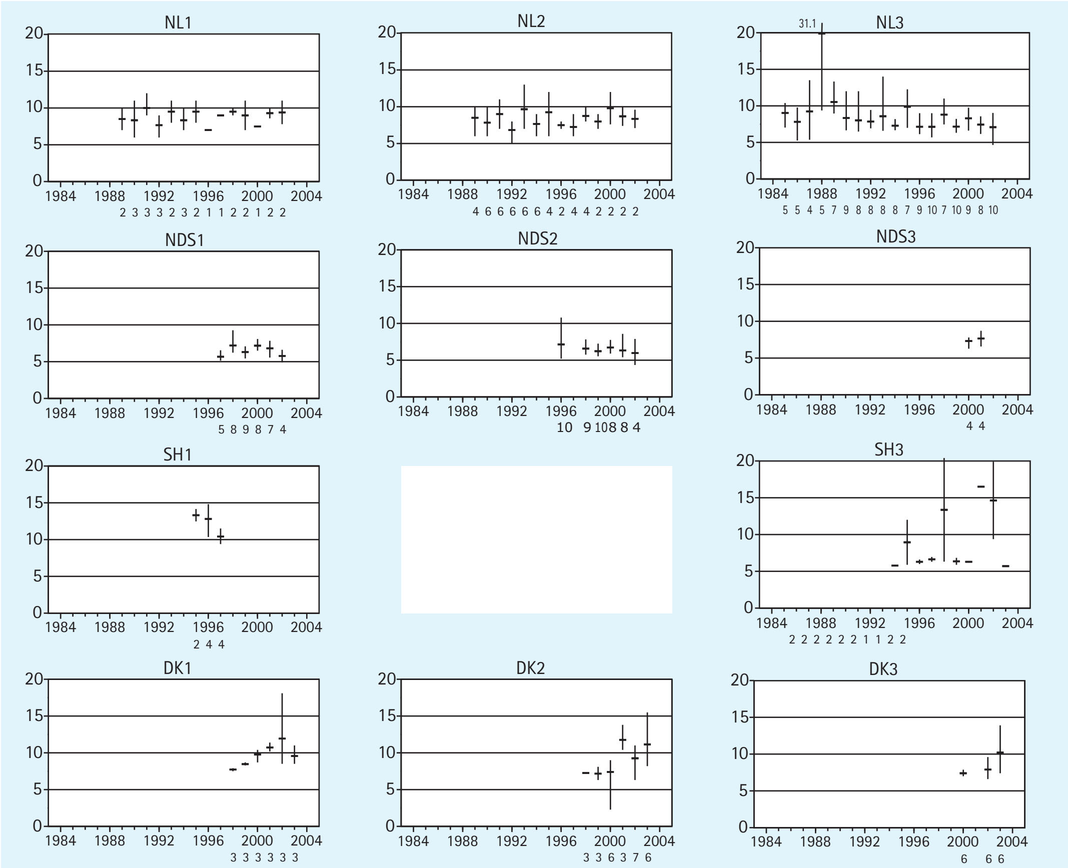
ment criterion in 2002-2003, the SH-subareas also in 2000.

Concentrations in blue mussel

Significant temporal trends could not be discerned due to large interannual and sample variation (Figure 4.2.9). In the subareas SH3 to DK3 the data suggests a rapid increase by a factor of 2 between 1997 and 2002. Subarea SH1 may show a reduction, following the strong reduction in Elbe input (see Figure 4.2.1).

Subareas NL3 to NDS3 exhibit the lowest levels in 2001-2002, whereas subarea SH3 shows the highest levels. Here, the proposed background (OSPAR, 1997, 2002; assuming 85% water in wet weight) is exceeded by a factor of 3. Concentrations in subareas NL3 to NDS3 are at the top of the proposed background. Concentrations in subareas NL1, NL2, SH1 and DK1 to DK3 are about twice the proposed background level.

Figure 4.2.9: Copper (Cu) contents in Wadden Sea blue mussel *Mytilus edulis* (mg·kg^{-1} dry weight). Average (–) and minimum/maximum range (|) is shown.



4.2.2.4 Mercury

Input

The dramatic reduction in Elbe mercury loads and concentration in 1994 was followed by a continued, but smaller decrease until 2002 (Figure 4.2.1). The Weser loads and concentrations peaked between 1991 and 1997. Uniquely, the Weser water concentration of mercury seems to increase with the river flow rate, indicating that the Weser mercury input depends on the atmospheric wet deposition rate. This may imply that, unlike the other rivers, the Weser input has its source predominantly in land run-off.

Year-averaged mercury concentrations, derived from OSPAR flux data, are over 10 times higher in the Elbe, Weser and Ems, than in Lake IJssel and Eider. The mercury concentrations tended to increase in Weser and Ems between 2000 and 2002.

Atmospheric input (Table 4.2.1) to the Dutch Wadden Sea is about 2% of the total riverine input into that area (Bellert *et al.*, 2004).

QSR 1999

A strong reduction of Elbe mercury input occurred by 1987 as a consequence of decreasing annual flow, but most dramatically between 1993 and 1994. The Elbe water mercury concentration started to decrease already in 1991, but dropped more than sixfold between 1993 and 1994. Mercury levels in biota of the Elbe estuary followed this trend, which was not observed in Elbe estuarine sediments. The Weser input and concentrations are suspected to be increasing. Mercury levels in the other Wadden Sea subareas are well below those in the Elbe subarea without showing a particular trend.

Concentrations in sediment

In the <63 µm sediment fraction, the most obvious downward trend was observed in subarea SH1 between 1996 and 2000, probably as a response to the decreased Elbe input (Figure 4.2.10). Due to overlap in interannual maxima and minima, however, this trend is not significant. The reduction of sediment concentrations can be estimated at 80-90% between 1996 and 2000. In the subareas NL1 to NDS2, a moderate downward trend has occurred in the past 18 years reaching a maximum reduction of about 70% in NL3. Subareas NDS1 to NDS3, SH2 and SH3 reached comparable levels in 2003 to 1984 with a slight elevation in between. In 2002/2003 averaged sediment mercury levels are a factor of 10 (NL1) to 3 (NDS1 to NDS3) higher than the background. Subareas SH1 and SH2 approached background value in 2000; no more recent data is available.

In all subareas, sediment concentrations were within the range of the provisional ecotoxicolog-

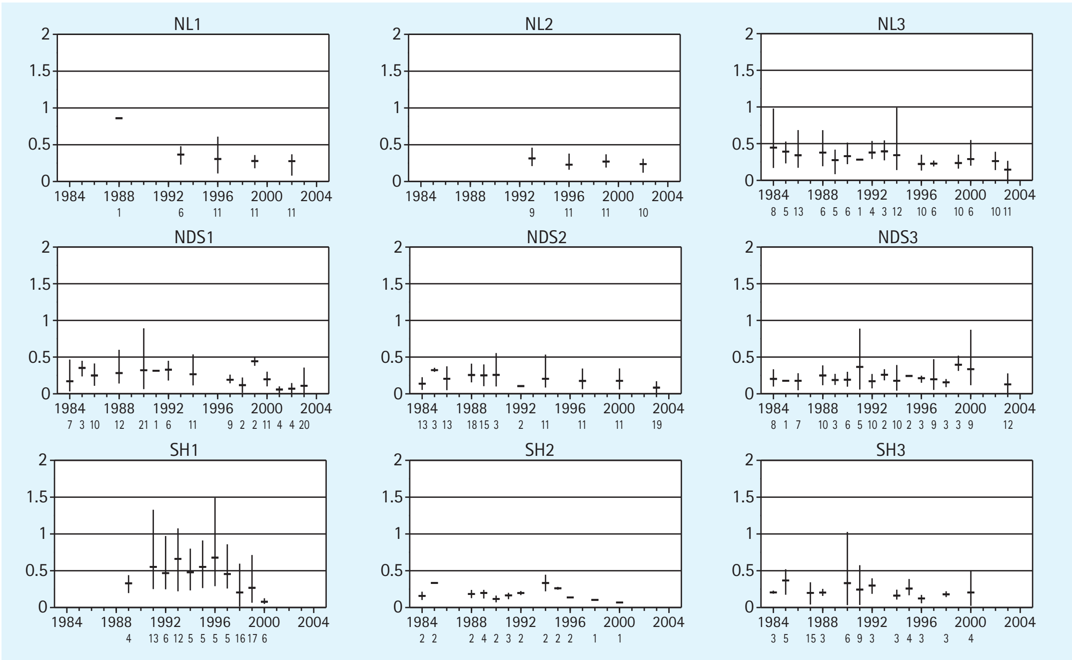


Figure 4.2.10: Mercury (Hg) contents in Wadden Sea sediments (mg·kg^{-1} dry weight in the fraction <63 µm). Average (—) and minimum/ maximum range (|) is shown.

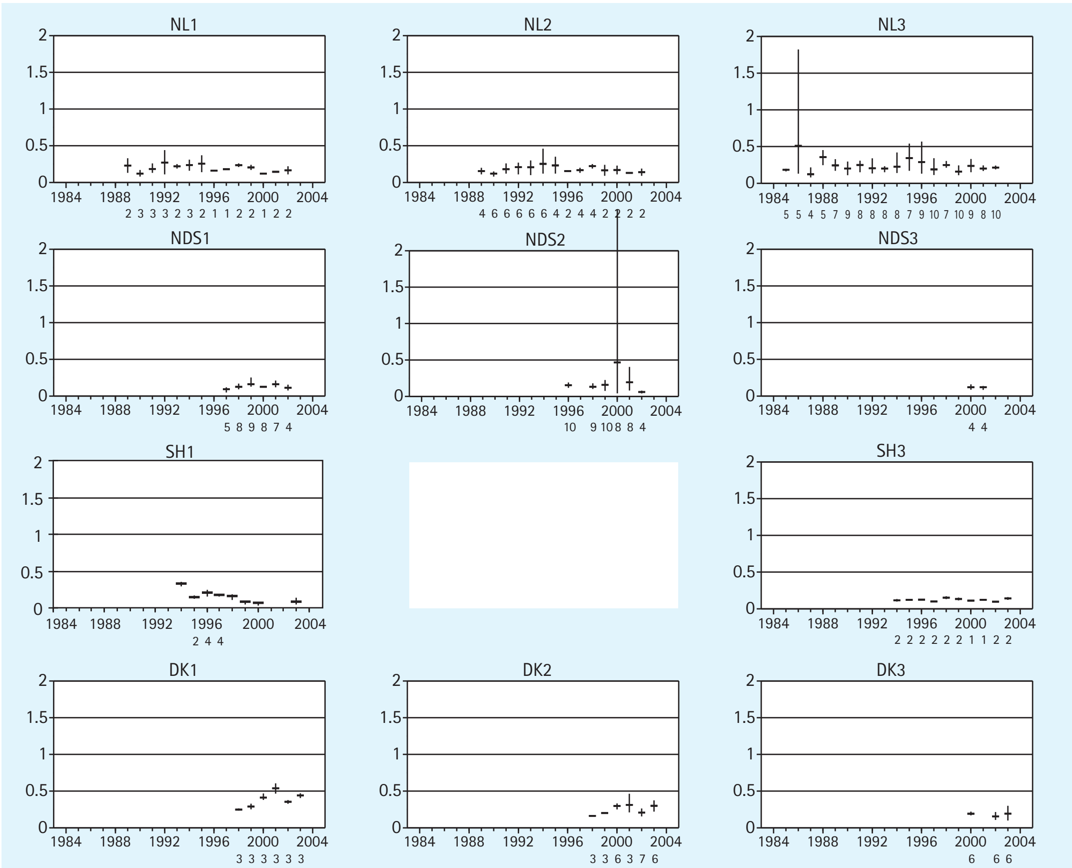


Figure 4.2.11: Mercury (Hg) contents in Wadden Sea blue mussel *Mytilus edulis* (mg·kg^{-1} dry weight). Average (—) and minimum/maximum range (|) is shown.

ical assessment criterion for mercury (OSPAR, 2004) in 2000/2003.

Concentrations in blue mussel

In subarea SH1, a significant reduction (factor 6) was realized between 1994 and 2000, following the strong decrease of Elbe input (Figure 4.2.11). Speculatively, the slight, insignificant increase in the 2003 data may have been caused by the Elbe 2002 flood. In subareas DK1 and DK2, however, a significant increase occurred of a factor of 2 between1998 and 2003. This might be the result of residual sediment transport mediated mercury contamination originating from the Elbe.

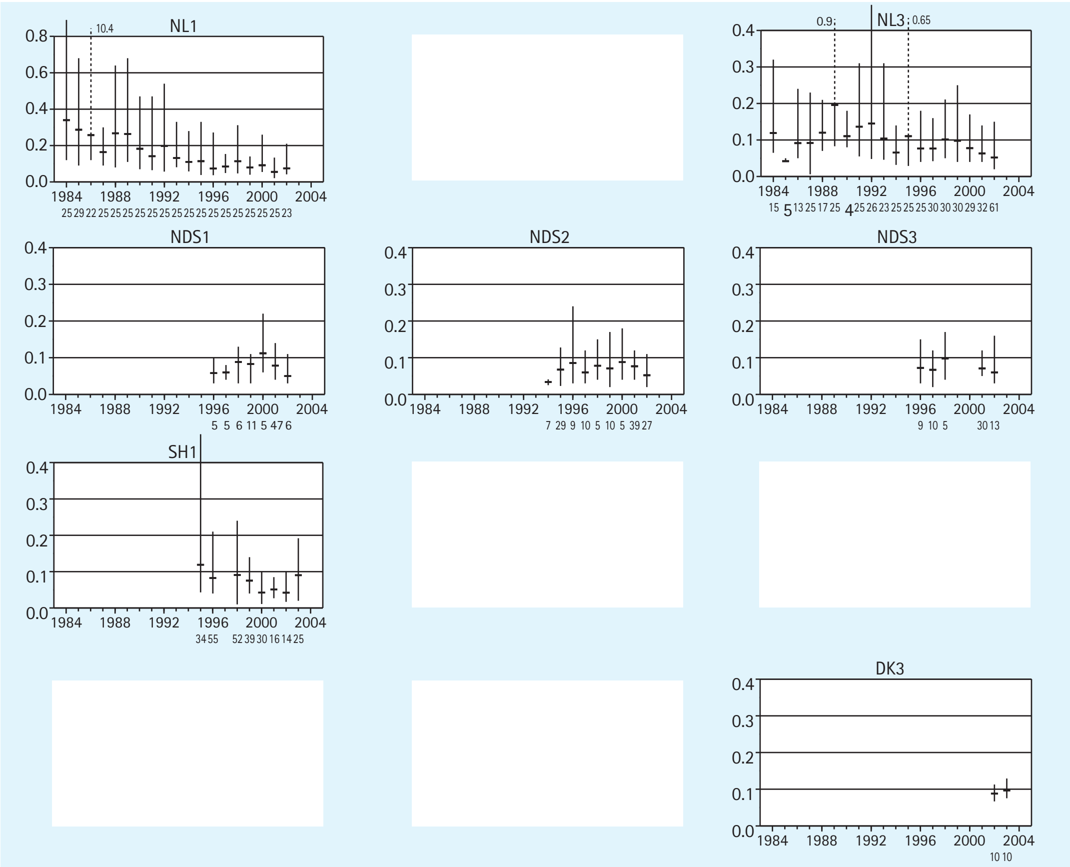


Figure 4.2.12: Mercury (Hg) contents in muscle of Wadden Sea flounder *Platichthys flesus* (mg·kg^{-1} dry weight). Average (–) and minimum/maximum range (|) is shown.

In most subareas, mercury levels were a factor 2 to 4 higher in 2002/2003 than the proposed background (OSPAR, 2002; assuming an average 85% water content). Lowest levels were reached in subareas SH1 and NDS2, though still at the high end of the background. Highest levels were found in subareas DK2 and DK1, exceeding the background by a factor of 6 and 9 respectively.

Concentrations in flounder

The high variability of mercury concentrations in flounder muscle tissue complicate trend detection (Figure 4.2.12). Based on a general decrease in maxima, a downward trend by a factor of 4 can be observed in subareas NL1, NL3 and SH1. In subarea SH1, the occurrence of higher maxima in 2003 may be related to the Elbe flood of 2002.

Assuming 80% water content in muscle tissue, mercury levels are within the proposed background range (OSPAR, 2004).

Concentrations in bird eggs

Mercury contents in eggs of the common tern (*Sterna hirundo*) and oystercatcher (*Haematopus ostralegus*) are reported in chapter 4.5. The initial strong decrease in this contents between 1981 and 1993 was continued, with the exception, however, of oystercatcher eggs from Trischen (SH1), where a significant upward trend occurred. Evaluation of the 6 year period 1998-2003 shows a significant upward trend for Balgzand (NL1), Trischen (SH1) and Langli (SH2) for mercury in oystercatcher eggs; at Minsener Oog (Jade) in common tern eggs, but no longer a significant trend in the Elbe subarea SH1.

The relatively high Balgzand levels cannot be related to the IJsselmeer input and probably originate from local sources. The relatively high levels at Trischen, however, may be related to the input from Elbe and Weser.

At the location of Minsener Oog (Jade, NDS3) concentrations in common tern eggs may be related to the mercury input from the Weser, which was increasing between 1998/2000 and 2002 both in flux and concentration, suggesting that the feeding grounds are in the Weser estuary.

4.2.2.5 Lead

Input

The dramatic reduction in the Elbe input and concentration stabilized at the 1994 level, with a slight increase up to 2002 (Figure 4.2.1).

The load and concentration in the Weser were variable with a slight overall increase (1985 compared with 2002). An intermediate concentration

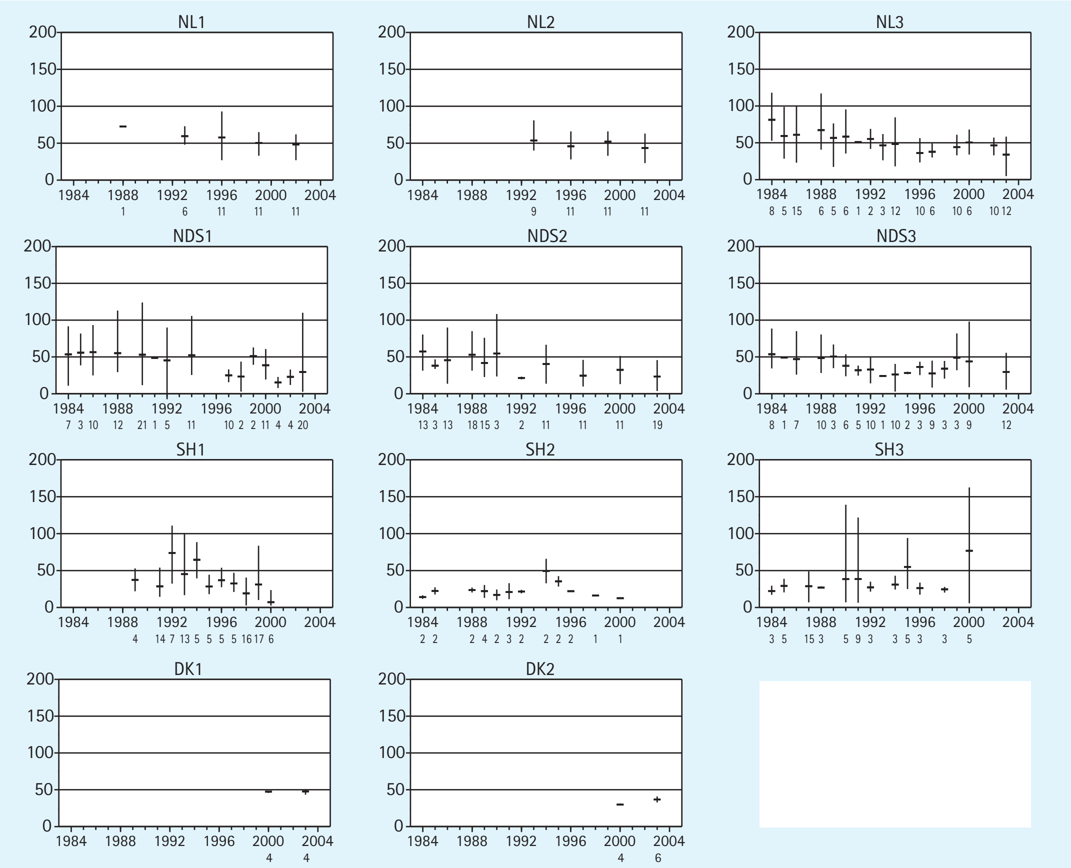


Figure 4.2.13: Lead (Pb) contents in Wadden Sea sediments (mg·kg⁻¹ dry weight in the fraction <63 µm). Average (–) and minimum/ maximum range (|) is shown.

and input peak (1991-1999) temporarily caused more than a doubling of concentration and input. Year-averaged concentrations of lead in Elbe and Weser water, derived from OSPAR flux data, were at the same level and 2-3 times higher than in Lake IJssel, Ems and Eider in 2002.

Lead input and concentrations of Lake IJssel and Ems did not show a significant trend. The Eider has a very small input compared to the other rivers, but both its input and water concentration were about twice as high in 1996 – 2002 compared to 1990 – 1995. The source, however, is unknown.

The atmospheric input of lead (Table 4.2.1) is about 4% of the total riverine input.

QSR 1999

The Elbe showed the strongest reduction in lead input between 1993 and 1994. This was reflected by decreasing levels blue mussels, but less prominent in sediments. The Weser showed large annual and periodical variations in both input and concentration which were suspected of increasing. Lead concentrations in the Weser surpassed those of the Elbe in the period 1994 – 1996. In the other Wadden Sea subareas no trends were detected.

Overall, lead concentrations in the Wadden Sea were close to background and within the ecotoxicological assessment criteria of OSPAR (1997).

Concentrations in sediment

Most subareas showed a downward trend of lead in sediment, which was most clear in subareas NL3 and SH1 (Figure 4.2.13). Significant trends cannot be determined due to large inter-sample variations, however both maxima and minima are decreasing. Particularly in subarea SH3, the maximum values of both original and standardized data tend to be associated with very low silt (less than 1% <20 µm) and relatively high contents of organic carbon (6 – 7 %) (Figure 4.2.14). Because the original analytical results in the silt fraction of the very sandy sediments are high, it can be concluded that at some sites in subarea SH3 the few silt particles present are a factor of 4-5 more contaminated. Since this phenomenon occurs specifically in subarea SH3 and with respect to lead and zinc associated with a low fraction <20 µm, it may originate from a local source which is probably related to shipping. Alternatively, it may turn out to be the result of cross-contamination. Since the copper anomaly in SH3 and DK2 is associated with low organic carbon content, this is presumably not related to sources.

Except in subareas SH1 to SH3, sediment lead levels frequently exceed the proposed background by a factor of 2-4. In subarea SH3, one location is

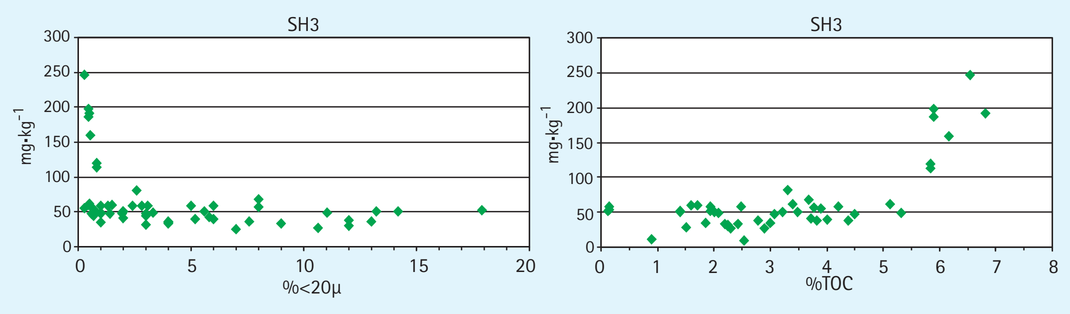


Figure 4.2.14: Lead (Pb) contents in Wadden Sea SH3 sediments (mg·kg⁻¹ dry weight in the fraction <20 µm) as function of the fraction <20 µm and of the total organic carbon content (%TOC). For anomalous high lead contents at low fractions <20 µm and high TOC values see text.

exceeding the background by a factor of 5-10.

In subareas NL1 to NDS3 and SH3, the sediment lead levels in 2000/2003 were frequently higher than the high end of the range of the provisional ecotoxicological assessment criterion for lead (OSPAR, 2004). The level at the one anomalous location in subarea SH3 was up to a factor of 4 higher.

Concentrations in blue mussel

Lead levels in subarea SH1 were reduced by a factor of 3 in the period 1994-1997, directly following the strong input reduction by the Elbe river (Figure 4.2.15). On the other hand, subareas DK1 and DK2 showed a trend increasing by a factor of 2 between 1998 and 2003.

Only in subareas NL1 to NL3 the lead content in blue mussels was 2-3 times higher than in the other subareas of the Wadden Sea (Figure 4.2.16). Proposed background levels are exceeded by up to 4 times, while in the other subareas levels are at the high end of the background (OSPAR, 2004; assuming 85% water content).

4.2.2.6 Zinc

Input

The period of drastic reduction of zinc input by the Elbe ended by 1997 (Figure 4.2.1). The Elbe and Weser had the higher zinc concentrations, being 4- to 8-fold the concentrations in Lake IJssel, Ems and Eider. Recent trends are nearly absent and mainly flow-related.

The atmospheric input of zinc (Table 4.2.1) to the Wadden Sea is about 1% of the summed riverine input.

Concentrations in sediment

As for most metals, the zinc levels in the sediment fraction < 63µm were variable, preventing any trend detection (Figure 4.2.17). Based on year-averaged data, however, most subareas showed a gradual downward trend during the last 18 years. In subarea SH1, there is no direct relationship to the strongly decreased Elbe input between 1994 and 1997.

QSR 1999

The Elbe showed the most dramatic drop in both input and concentration of zinc between 1993 and 1994. Zinc concentrations in both sediments and mussels followed this trend. The Elbe input of zinc influenced the entire Schleswig-Holstein Wadden Sea area.

Other Wadden Sea subareas displayed no significant input trends. The same holds for sediments, except for the western and eastern Dutch Wadden Sea. Possible reduction of zinc in sediments (Ems estuary) and mussels (Jadebusen) after a peak period was noted. Zinc concentrations were near the background level by 1996.

The extreme values in subarea SH3 are related to the sandy nature of the sediments, containing very little silt (see above). Except for DK1, concentrations in all subareas were at or below the proposed background. In subarea SH3, one sandy location with very low silt content exceeded the background by a factor of 5 in 2000. At this same location, where also higher copper and lead levels were found (see above), the upper limit of the provisional ecotoxicological assessment criterion for zinc was reached (OSPAR, 2004). In all other subareas of the Wadden Sea, concentrations were below this criterion.

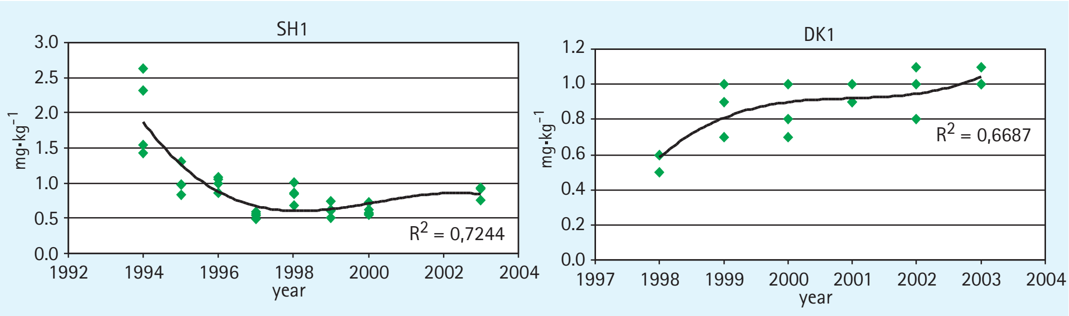


Figure 4.2.15: Lead (Pb) contents in Wadden Sea subareas SH1 and DK1 blue mussel *Mytilus edulis* (mg·kg⁻¹ dry weight). The SH1 trend line shows a direct reduction following the Elbe input pattern (see Figure 4.2.1). In DK1 the trend is increasing.

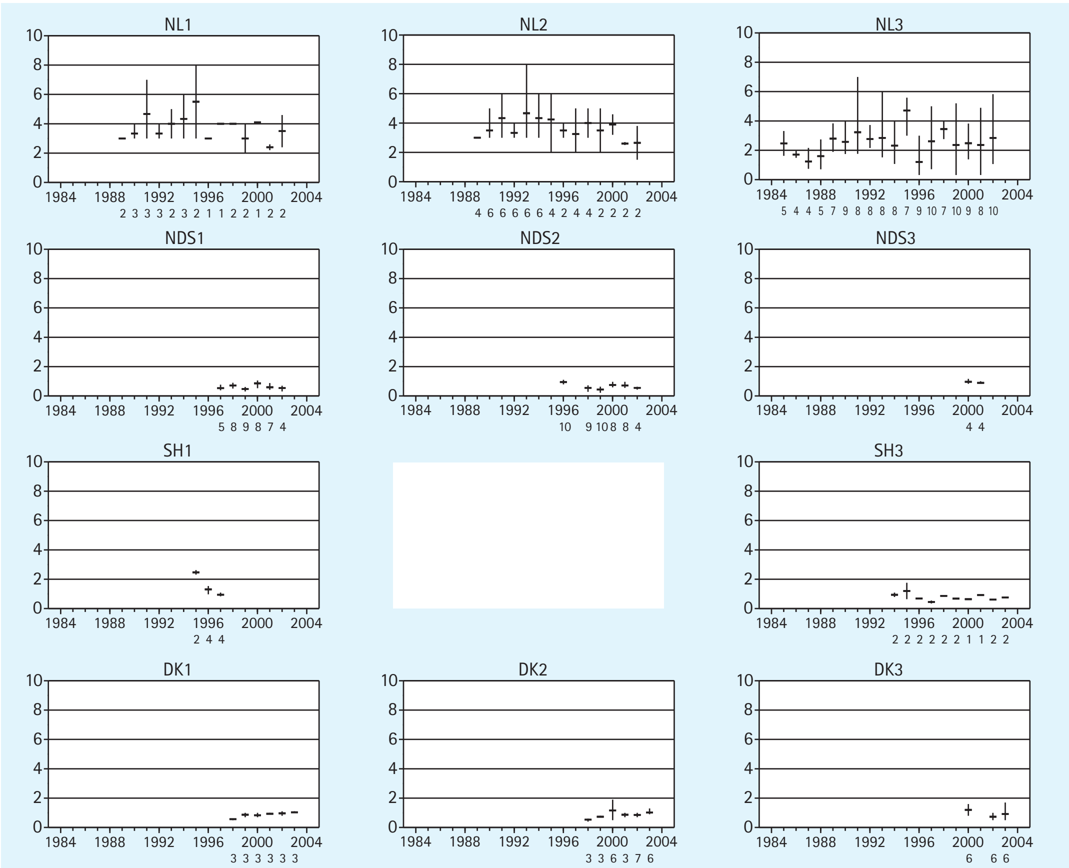


Figure 4.2.16: Lead (Pb) contents in Wadden Sea blue mussel *Mytilus edulis* (mg·kg^{-1} dry weight). Average (–) and minimum/maximum range (|) is shown.

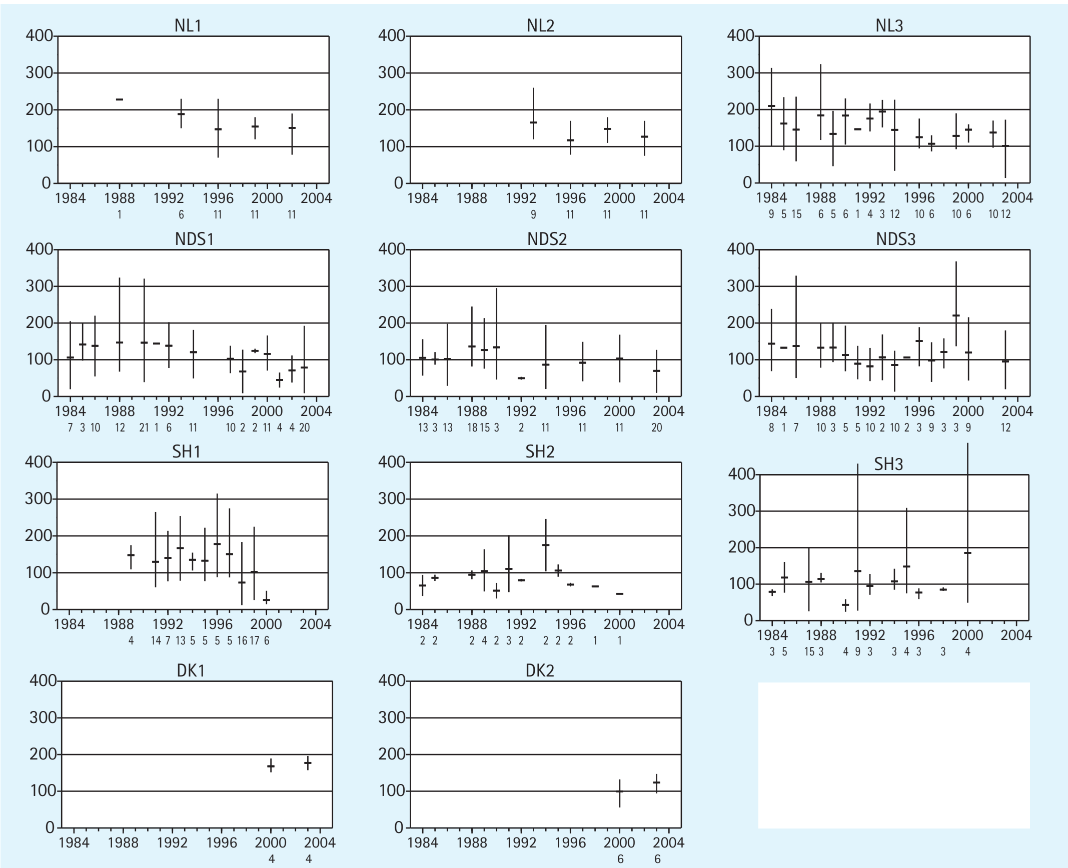


Figure 4.2.17: Zinc (Zn) contents in Wadden Sea sediments (mg·kg^{-1} dry weight in the fraction <63 µm). Average (–) and minimum/ maximum range (|) is shown.

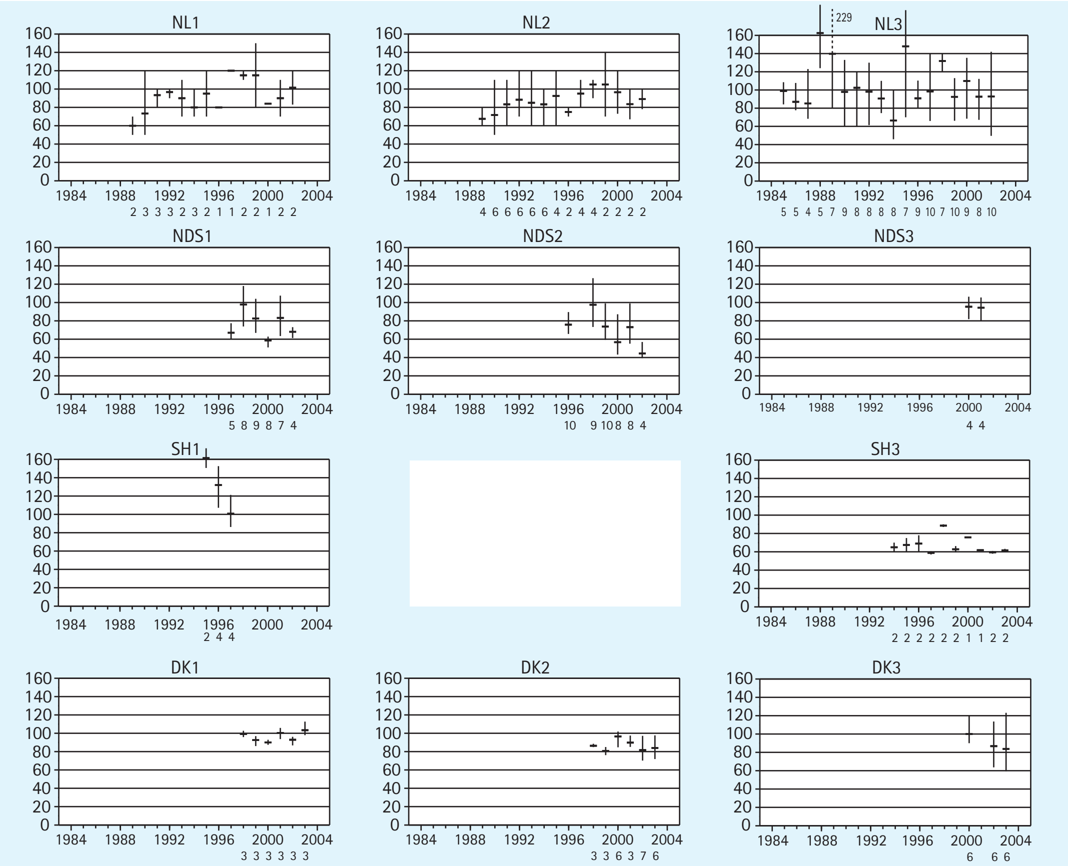


Figure 4.2.18: Zinc (Zn) contents in Wadden Sea blue mussel *Mytilus edulis* (mg·kg^{-1} dry weight). Average (–) and minimum/maximum range (|) is shown.

Concentrations in blue mussel

It is well known that blue mussels are capable of regulating specifically their internal zinc concentrations through the formation of metallothionines. Nevertheless, despite the variable concentrations, a distinct upward trend between 1989 and 1999 can be discerned in subarea NL1 and to a lesser extent in NL2 (Figure 4.2.18). On the other hand, subareas SH1 and NDS2 show a decrease in zinc concentrations between 1996 and 2002.

As a result of the increase subareas NL1 to NL3, NDS3, SH1and DK1 were all at the comparable level of about 100 mg kg^{-1} dry weight in 2002. Lowest levels were found in subarea NDS2, followed by NDS1, SH3, DK2 and DK3. Zinc levels are at proposed background levels in all subareas of the Wadden Sea (OSPAR, 2004; assuming 85% water content).

4.2.2.7 Summary of metal trends and target evaluation

- Major reductions in input and concentration of metals in the Wadden Sea mainly occurred in the late 1980s until the early 1990s, continuing moderately until 2002.
- The Elbe region (subarea SH1) is an exception, where levels of cadmium, mercury, lead and, only in blue mussels, zinc decreased in the late 1990s.
- The proposed background in sediments was exceeded by mercury (factor 3-10) and lead (factor 2-4) and thus the Target was not met. Zinc exceeded the background only in subarea DK1 (by a factor 2).
- Cadmium (factor 2-3), copper (factor 3 in SH3), mercury (factor 2-9) and lead (factor 2-4 in NL1 to NL3) are exceeding the proposed blue mussel background and thus the Target.
- At one anomalous location in subarea SH3, the backgrounds of copper, lead and zinc were exceeded. Also the Ecological Assessment Criterion (EAC) for zinc was exceeded at this one sandy location. A similar situation was observed in subarea DK2 for the EAC for copper. Whether this is real or an analytical or cross-contamination error needs to be investigated. The sources of copper and both lead and zinc are presumably not the same.
- Incidents, such as the Elbe flood of 2002, showed short-term effects only (increased cadmium and mercury levels in flounder liver and muscle respectively). This effect could not be demonstrated in sediment or blue mussels due

to the absence of data for these matrices and for other metals.

Nickel, a new compound of high priority in both OSPAR and Water Framework Directive, needs to be included in the monitoring of the Wadden Sea.

Harmonization of methods to improve comparability, and quality and availability of data stored in databases has progressed little since the 1999 QSR, neither for JAMP nor TMAP.

4.2.3 Organic micropollutants (PAHs)

4.2.3.1 Data

The availability of data for polyaromatic hydrocarbons (PAHs) is limited to concentrations in sediments and blue mussels (*Mytilus edulis*) reported to OSPAR. This concerns the '6 of Borneff' (Fluoranthene, Benzo-b/k-Fluoranthene, Benzo-a-Pyrene, Indeno-123, cd-Pyrene, and Benzo-ghi-Perylene).

4.2.3.2 Inputs

No data is available for riverine inputs, in part because PAHs dissolve poorly in water. Atmospheric input of PAHs has been reported for the Dutch Wadden Sea for 2000 and 2001 from modelling and ground station data (Duyzer and Vonk, 2002; Table 4.2.2). An average of ca. 800 kg y^{-1} of 6 of Borneff PAHs is deposited in the Dutch Wadden Sea. Except for dibenzo(ah)anthracene, the input in 2001 was on average 40% lower than in 2000.

	Dutch Wadden Sea	
Compound	**2000 (kg/y)**	**2001 (kg/y)**
Acenaphthene	712	461
Acenaphtylene	19	22
Anthracene	60	35
Benzo(a)anthracene	23	17
Benzo(a)pyrene	36	31
Benzo(b)fluoranthene	72	78
Benzo(ghi)perylene	33	34
Benzo(k)fluoranthene	46	61
Chrysene	71	46
Dibenzo(ah)anthracene	4	10
Phenanthrene	1863	1442
Fluoranthene	553	590
Fluorene	1142	711
Indeno(123,ghi)pyrene	29	34
Naphthalene*	1188	1017
Pyrene	274	296
Sum ^{6}Borneff (bold)	769	828

Table 4.2.2: Atmospheric input of PAHs into the Dutch Wadden Sea. Bold: 6 of Borneff PAH, *= volatile (source: Duyzer and Vonk, 2002).

4.2.3.3 Concentrations in sediments

The sum of 6 of Borneff PAHs in the sediment fraction <63 µm is plotted in Figure 4.2.19. No significant trends were observed, while subareas NL1-NL3 are at an equal level of about 0.5 mg kg^{-1} dry weight. Average levels in subarea NL2 tend to increase consistently between 1988 and 2002. The same picture occurs when standardized to 5% organic carbon in the sediment (Figure 4.2.20).

Danish PAH data were available in a non-comparable format only, whereas the two-year series allows no trend assessment either.

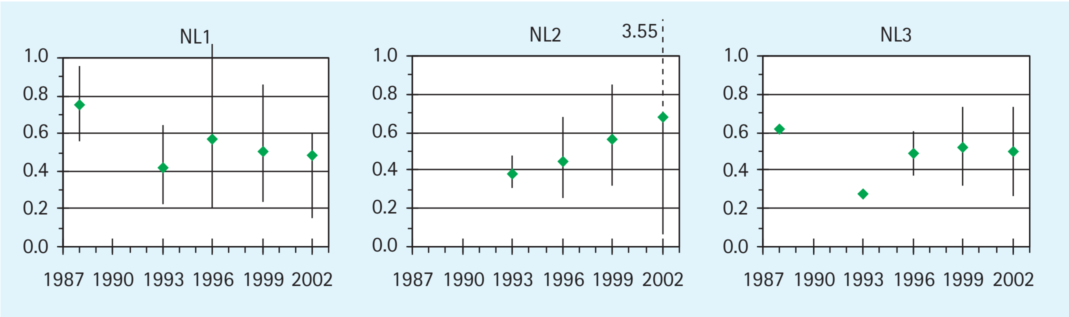


Figure 4.2.19: Sum of 6 of Borneff PAHs (mg kg^{-1} dry weight) in the sediment fraction < 63 µm in the Dutch Wadden Sea. Bars indicate minimum/ maximum values.

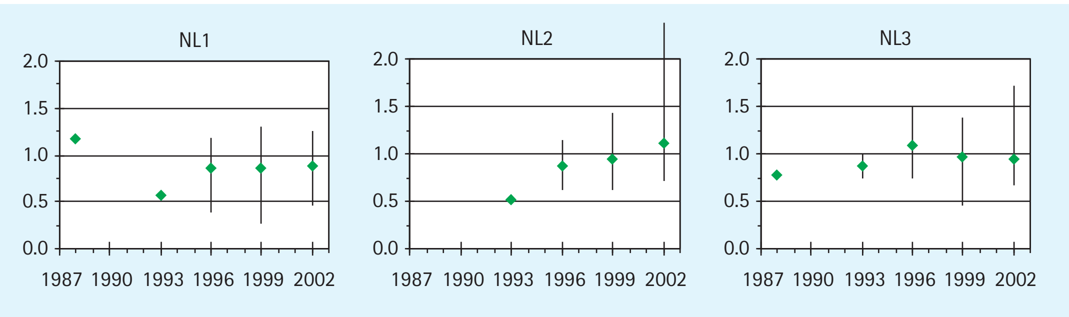


Figure 4.2.20: Sum of 6 of Borneff PAHs (mg kg^{-1} at 5% organic carbon) in the sediment fraction < 63 µm in the Dutch Wadden Sea. Bars indicate minimum/ maximum values.

Table 4.2.3: Agreed Ecotoxicological Assessment Criteria by OSPAR (2004). Sediment was not unambiguously defined, it is assumed that the < 63 µm fraction was meant. For wet weight to dry weight conversions: mussel was set at 85% WW and flounder at 80% WW (muscle tissue). DW = Dry weight, WW = wet weight. f: firm; p: provisional, n.d.: no or insufficient data available, n.r.: not relevant to current JAMP.

Compound	Water ($\mu g\ l^{-1}$)	Sediment ($mg\ kg^{-1}$ DW)	Fish ($mg\ kg^{-1}$ WW)	Mussel ($mg\ kg^{-1}$ DW)
As	1-10	1-10		
Cd	0.01-0.1	0.1-1		
Cr	1-10	10-100		
Cu	0.005-0.05	5-50		
Hg	0.005-0.05	0.05-0.5		
Ni	0.1-1	5-50		
Pb	0.5-5	5-50		
Zn	0.5-5	50-500		
DDE	n.r.	0.0005-0.005 (p)	0.005-0.05 (f)	0.005-0.05 (f)
Dieldrin	n.r.	0.0005-0.005 (p)	0.005-0.05 (f)	0.005-0.05 (f)
Lindane (γ-HCH)	0.0005-0.005 (f)	n.r.	0.0005-0.005 (f)	n.r.
Napthalene	5-50 (f)	0.005-0.5 (f)	n.r.	0.5-5 (p)
Phenanthrene	0.5-5 (p)	0.1-1 (f)	n.r.	5-50 (p)
Anthracene	0.001-0.01 (p)	0.05-0.5 (f)	n.r.	0.005-0.05 (p)
Fluoranthene	0.01-0.1 (p)	0.5-5 (p)	n.r.	1-10 (p)
Pyrene	0.05-0.5 (p)	0.05-0.5 (p)	n.r.	1-10 (p)
Benzo-a-Anthracene	n.d.	0.1-1 (p)	n.r.	n.d.
Chrysene	n.d.	0.1-1 (p)	n.r.	n.d.
Benzo-k-Fluoranthene	n.d.	n.d.	n.r.	n.d.
Benzo-a-Pyrene	0.01-0.1 (p)	0.1-1 (p)	n.r.	5-50 (p)
Benzo-ghi-Perylene	n.d.	n.d.	n.r.	n.d.
Indeno-123,cd-Pyrene	n.d.	n.d.	n.r.	n.d.
Sum^7 PCB	n.r.	0.001-0.01 (p)	0.001-0.01 (f)	0.005-0.05 (f)
TBT	0.00001-0.0001 (f)	0.000005-0.00005 (p)	n.r.	0.001-0.01 (f)

4.2.3.4 Summary of trends and target evaluation

The available data on organic micropollutants does not show a significant trend neither in deposition nor in sediment content.

The sediment content of PAHs in the Wadden Sea is slightly elevated when compared to Barents Sea sediments (~0.87 mg kg^{-1} at 5% organic carbon), but well below Skagerrak sediments (~2.36 mg kg^{-1} at 5% organic carbon). No natural background was denoted by OSPAR (2004).

For individual PAHs, ecotoxicological assessment criteria were agreed by OSPAR (2004), a few of which are firm (Table 4.2.3). None of the PAHs exceeded the range of these ecotoxicological assessment criteria.

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Joop F. Bakker
Martine van den Heuvel-Greve
Dick Vethaak

4.3.1 Introduction

Compounds which are not of biogeochemical origin and usually solely man-made are referred to as 'xenobiotics', unknown to nature as we know it. A large variety of xenobiotics are included in the 'List of chemicals for priority action' (OSPAR, 2002) and the proposed 'Priority list' of the Water Framework Directive. Some compound groups, however, though classified as xenobiotics have been found to be produced in minute amounts by versatile micro-organisms such as fungi (Hoekstra and de Leer, 1995). Most of the PBT criteria (Persistant, Bioaccumulative, Toxic) apply to xenobiotic compounds, making them environmentally hazardous. An important, newly emerging mode of 'toxicity' from many xenobiotics is hormonal disruption (see chapter 4.6).

Target

Concentrations of man-made substances as resulting from zero discharges

The 1999 QSR summarized that, in general, riverine inputs and concentrations in sediment and biota of most of the investigated xenobiotics had decreased, but that for some compounds elevated concentrations could still be observed, especially with regard to tributyltin (TBT).

4.3.2 PCBs

4.3.2.1 Input

Riverine inputs of PCBs as reported by OSPAR are shown in Figure 4.3.1. The Elbe shows the most remarkable decrease in PCB input between 1988 and 1991. The dry year of 1996 rendered a relative peak in PCB input and water concentration in the Weser and Ems. The relative peak concentration of PCBs was highest in the Weser and Ems. Whether concentration peaks and relatively dry years correlate is still not clear (cf. de Jong *et al.*, 1999). PCB inputs have not reported for the Eider since 1997 and not for the Elbe since 2000. Weser and Ems water concentrations are amongst the highest, being about twice as high as in Lake IJssel. Weser inputs seem currently the highest, in the absence of data for the Elbe and Eider.

Atmospheric input as modelled for the Dutch Wadden Sea by Duyzer and Vonk (2002) is presented in Table 4.3.1. This limited data suggests a reduction between 2000 and 2001; confirmation by extended monitoring is required.

Disposal of dredged material from harbors in estuaries is a displacement of deposited mainly marine suspended particulate matter (SPM). The physical impact by volume and the trend in contaminant levels may be considered as quality cri-

QSR 1999

The Elbe input reduced dramatically between 1989 and 1991. The inputs of Lake IJssel, Ems, Weser and Eider fluctuate around a comparable level. It is suggested that river flow reduction after a wet period causes a concentration increase in the first year after the reduction. The following years PCB concentrations drop again.

PCB concentrations in sediments, mussel and bird eggs show a negative trend between 1985 and 1991 of 50 – 75%. In the case of the Elbe this was clearly correlated with the riverine input, which increased again between 1994 and

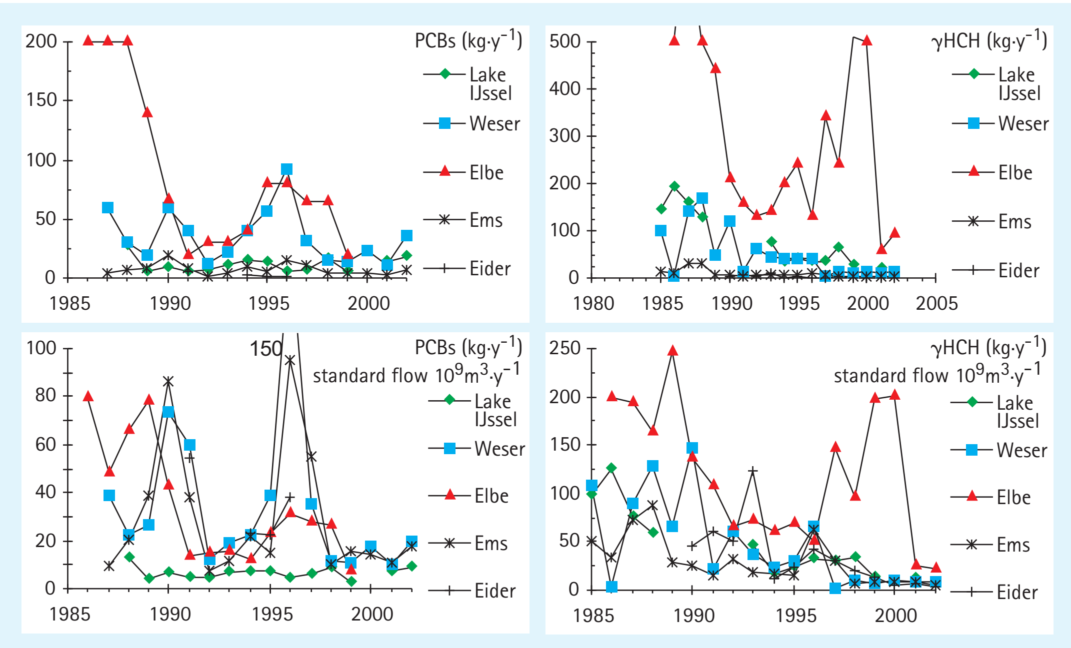


Figure 4.3.1: OSPAR reported fluvial PCBs and Lindane (γ-HCH) emissions (kg·y⁻¹) into the Wadden Sea. Top panels show actual input rates bottom panels at standardized flow (10^9 $m^3·y^{-1}$) (sources: D: Umweltbundesamt; NL: Rijkswaterstaat).

Table 4.3.1: Atmospheric deposition of Sum of 6 PCB congeners in the Dutch Wadden Sea area (source: Duyzer and Vonk, 2002.

	Dutch Wadden Sea	
Compound	2000 (kg y^{-1})	2001 (kg y^{-1})
Sum of CBs 28, 101, 118, 138, 153, 180	9.2	2.9
Lindane (γ-HCH)	30	15
Sum o,p'-DDD (Dichlorodiphenyldichloroethane) / DDE (Dichlorodiphenyldichloroethylene)	7	1
Hexachlorobenzene	3	2

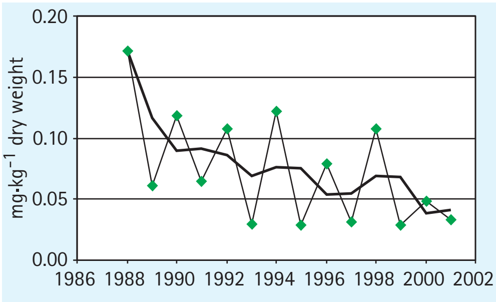


Figure 4.3.2: Trends in PCB concentrations in Rotterdam harbour dredged material (mg kg^{-1} dry weight, fraction < 2 mm) disposed of at sea (source: OSPAR, 2003).

teria (OSPAR, 2003). As an example, the trend of PCB concentrations in Rotterdam harbour sludge (fraction <2 mm) shows a 75% reduction between 1988 and 2001 (Figure 4.3.2). Most of the Rotterdam harbor sludge is disposed off in the Dutch North Sea coastal waters, from where the material is transported towards the western Dutch Wadden Sea.

4.3.2.2 Concentrations in sediment

No data is available for the German and Danish Wadden Sea. In subarea NL1, the sum of 6 PCBs (Σ^6PCB) in the <63 µm fraction of the sediment decreased, causing the disappearance of the geographical trend of concentrations decreasing from west to east as present in 1993 and 1996 (Figure 4.3.3).

Assuming that congener PCB 52 represents 1% of the Σ^7PCB, the maximum concentrations recorded in subarea NL1 for Σ^6PCB exceed the ecotoxicological assessment criterion of OSPAR.

4.3.2.3 Concentrations in blue mussel

Σ^6PCB values show variable trends and non-explainable variations in some subareas (Figure 4.3.4). In the northern Wadden Sea (subareas SH3 to DK2) a significant decrease occurred between 1994 and 2003. The levels in subareas SH3 to DK3 are about 25 µg kg^{-1} dry weight, compared to ~80 µg kg^{-1} dry weight in subareas NL1 and NL2. In NL1 and DK3 no further decrease in concentrations occurred between 2000 and 2002/03.

The data in subareas NL3 to SH1 is difficult to interpret due to extreme and non-explainable interannual variations. In all these subareas the over-

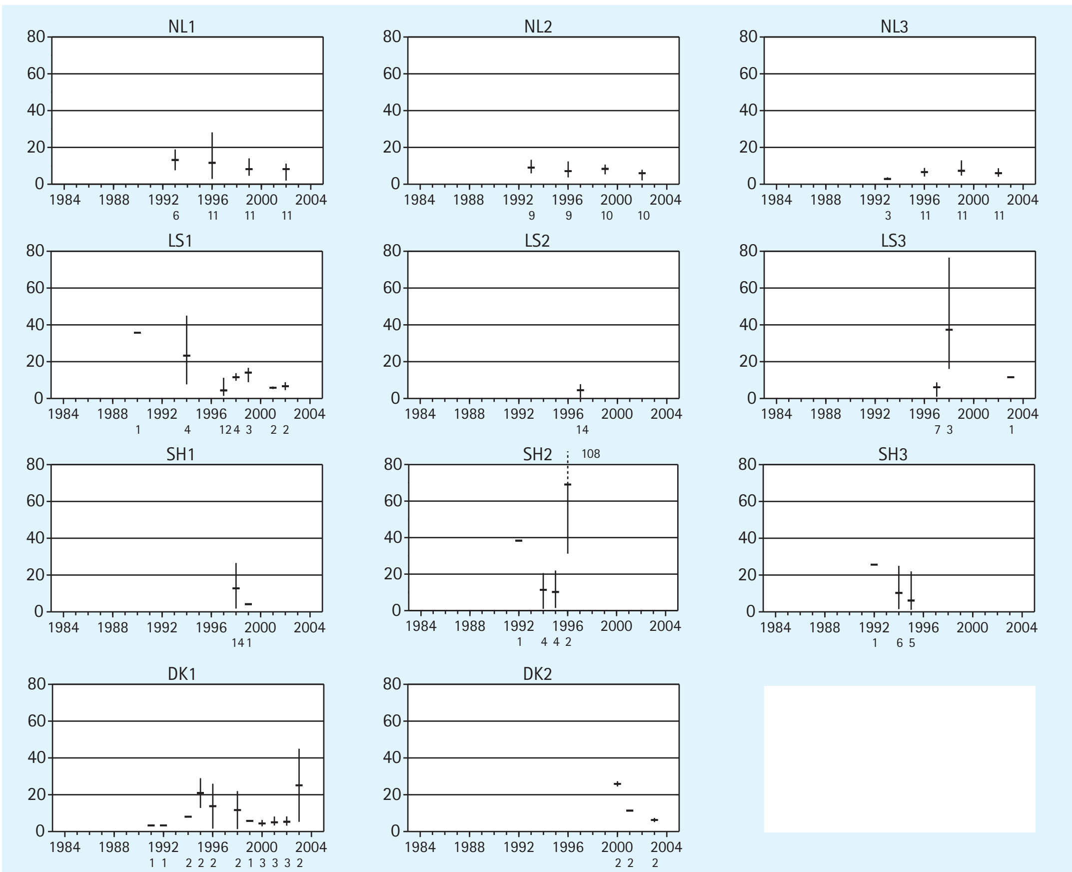


Figure 4.3.3: Average Σ^6PCB (PCB 28, 101, 118, 138, 153, 180) contents of sediment (µg kg^{-1} at 5% organic carbon). In recalculation to Σ^7PCB (including PCB 52) for comparison with OSPAR data, it was assumed that PCB 52 represents 1% of the mixture. Vertical lines represent the range between maximum and minimum data.

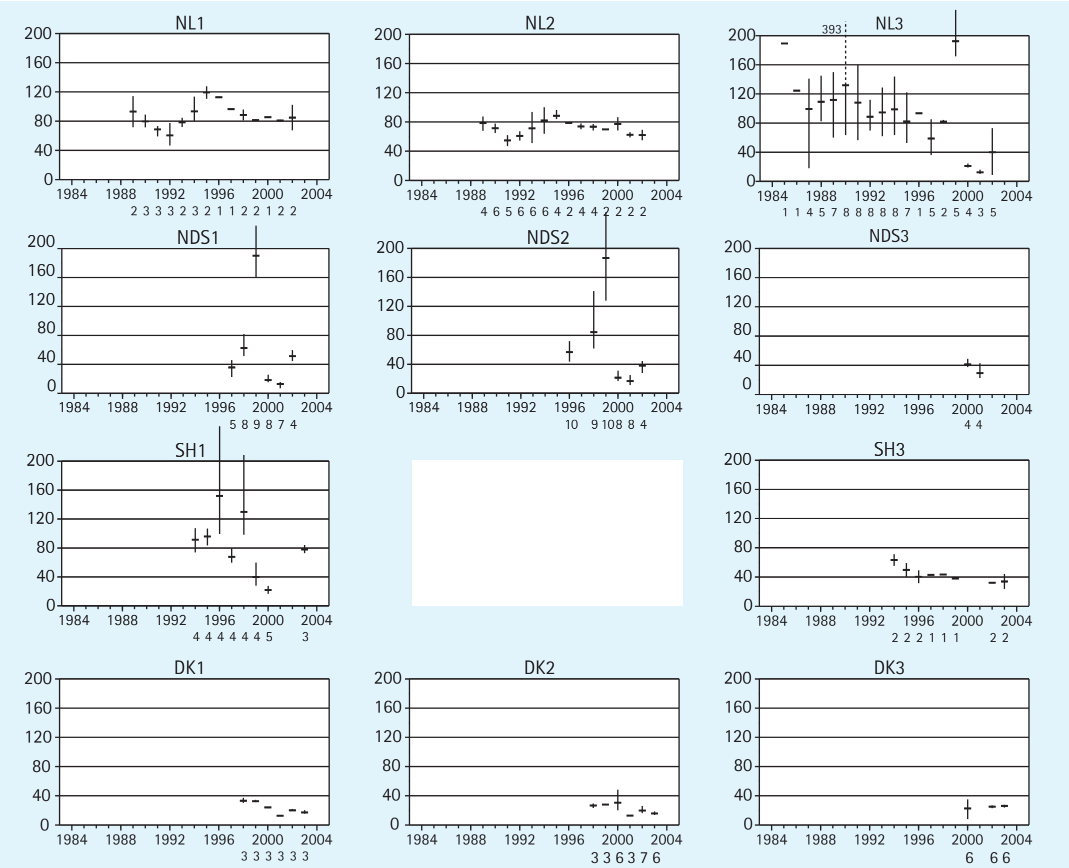


Figure 4.3.4: Average Σ^6PCB (PCB 28, 101, 118, 138, 153, 180) contents of blue mussel (*Mytilus edulis*) tissue (µg kg^{-1} dry weight). In recalculation to Σ^7PCB (including PCB 52) for comparison with OSPAR data, it was assumed that PCB 52 represents 1% of the mixture. Vertical lines represent the range between maximum and minimum data.

all trend seems to be downward, reaching a level of about 40 µg kg^{-1} dry weight in 2002/03, which is intermediate between NL1, NL2 and DK1 to DK3.

The concentrations of Σ^6PCB in blue mussels exceed the OSPAR (2004) maximum background range by a factor of 6 (DK) to 35 (NL), assuming an 85% water content of the blue mussel tissues. Based on Σ^6PCB and taking into account a 1% contribution of PCB 52 in Σ^7PCBs, concentrations in the Danish Wadden Sea are within the range of the firm ecotoxicological assessment criterion (OSPAR, 2004). Concentrations in subareas NL3 to SH3 are at the maximum of the range, and in NL1 and NL2 exceeded the range up to a factor of 2.

4.3.2.4 Concentrations in flounder liver

The longest available time series (for subarea NL3), Σ^6PCB concentrations show a consistent decrease from 1986 to about 1998. Since then, no further decrease seems to occur (Figure 4.3.5). For other subareas of the Wadden Sea data series are much shorter, and do not show an overall trend

Recent Σ^6PCB levels in flounder liver are comparable in subareas NL1 to SH1 (about 100 µg kg^{-1} wet weight). In subarea DK3, levels are a factor 6-7 lower (16 µg kg^{-1} wet weight). The concentrations in subareas NL1 to SH1 are at the maximum, those in subarea DK3 at the lower end of the firm ecotoxicological assessment criterion (EAC) (OSPAR, 2004). Adult flounders exceed the maximum EAC by a factor of 2 to 4.

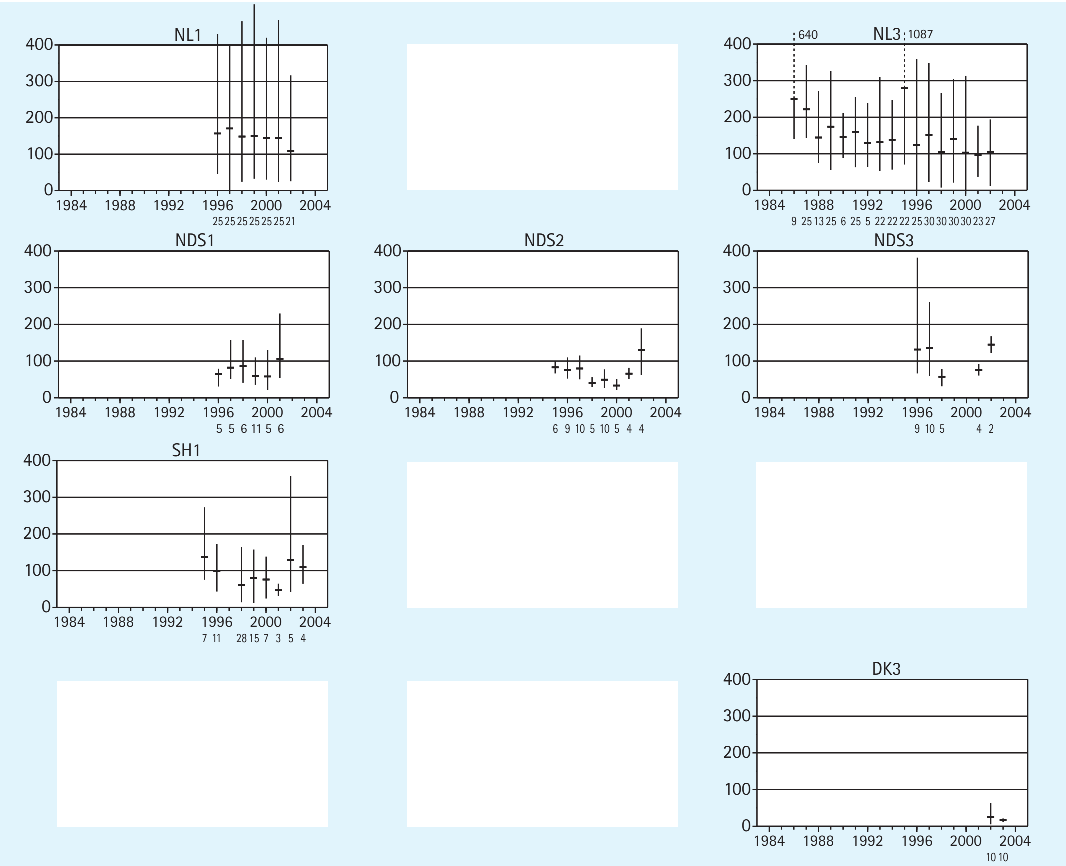
4.3.2.5 Concentrations in bird eggs

The long-term data for concentrations of PCBs in eggs of the common tern and oystercatcher show a rather strong decrease until ca. 1992, after which trends were not clear any more. In recent years in some subareas of the Wadden Sea, concentrations seem to be increasing again (see chapter 4.5).

The concentrations of Σ^6PCB congeners in common tern (*Sterna hirundo*) in 2002 show a spatial gradient of values decreasing from west (NL1) to north (DK3), with the Elbe estuary (SH1) being an exception and showing the highest values (Figure 4.5.2). In the oystercatcher (*Haematopus ostralegus*) the PCB concentrations are more equally distributed, with the exception of Skallingen (DK3), where concentrations are lower by a factor of 4-5.

Concentrations in eggs of the common tern are on average twice as high as in eggs of the oystercatcher. This can be attributed to the higher trophic level, and therefore a higher biomagnification factor, of the common tern, a fish eater, as compared to the oystercatcher, a benthos eater.

Figure 4.3.5: Average Σ^6PCB (PCB 28, 101, 118, 138, 153, 180) contents of flounder (*Platichthys flesus*) liver tissue (µg kg^{-1} wet weight). In recalculation to Σ^7PCB (including PCB 52) for comparison with OSPAR data, it was assumed that PCB 52 represents 1% of the mixture. Vertical lines represent the range between maximum and minimum data.



4.3.3 Lindane (γ-HCH)

Lindane is a neurotoxin and energy metabolism inhibitor. Crustaceans are especially sensitive; the inhibiting effect on carbohydrate metabolism affects winter survival. The compound is carcinogenic and active as an endocrine disrupter in birds and mammals. Metabolism is impeded by presence of chlorobenzenes. Lindane is still used in creams and shampoos to control lice and mites.

Lindane is one of the hexachlorocyclohexane isomers and most frequently used, but is in fact the one of least environmental concern. The β-HCH isomer, always occurring in the technical Lindane mixture, is considered a larger problem, since it was observed as the predominant environmental pathway of the relatively well water-soluble HCHs (Deutch *et al.*, 2002) and was found more frequently in human blood and breast milk (WWF, 2004). The available data for the Wadden Sea does not show accumulation of HCH isomers other than Lindane in blue mussels and flounder liver.

QSR 1999

The Elbe input of Lindane (γ-hexachlorocyclohexane) sharply decreased between 1985 and 1992 and showed an intermediate peak between 1993 and 1996. The Lindane input pattern was correlated with the flow rate pattern of the River Elbe. Lake IJssel, Weser and Ems showed a comparable reduction between 1985 and 1996.

The input reduction was reflected in Lindane concentrations in bird eggs, except in the Eider area (subarea SH2) in eggs of the common tern (*Sterna hirundo*). Lindane water concentrations were within the range of the OSPAR provisional ecotoxicological assessment criterion (EAC) of 5-50 ng·l^{-1}.

4.3.3.1 Input

The Lindane input by the Elbe and water concentrations dramatically increased between 1996 and 2000, followed by a similarly dramatic decrease in 2001 (Figure 4.3.1). The cause of the increasing Lindane input and concentrations in the late 1990s, equalling 1986 levels, is not known. A relation with the Elbe flood (August 2002) is not likely, because the increase started as early as in 1996. The other rivers showed an ongoing decrease throughout the assessment period.

4.3.3.2 Concentrations in blue mussel

Most subareas of the Wadden Sea show a downward trend (Figure 4.3.6). Subarea SH1, however, showed a significant increase between 1994 and 1998, which suddenly collapsed in 1999. During recent years, Lindane levels in blue mussels were at the same level in all subareas of the Wadden Sea.

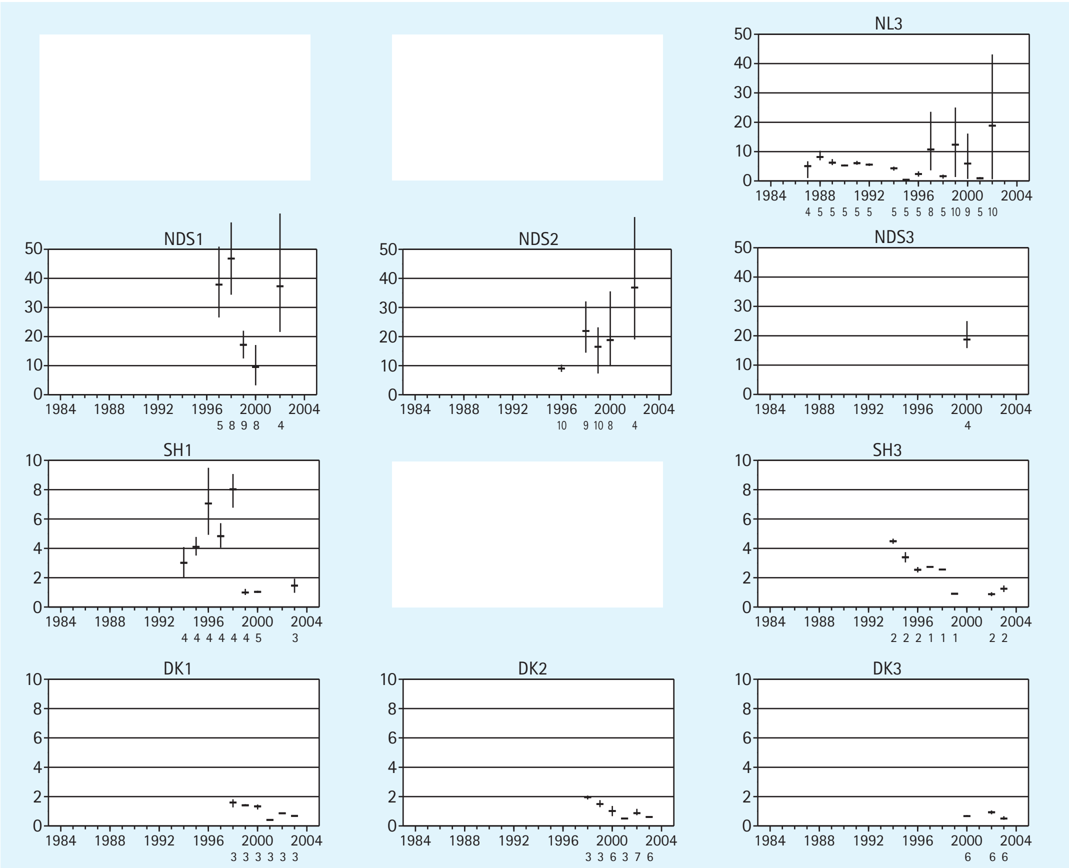


Figure 4.3.6: Average Lindane (γ-HCH) contents of blue mussel (*Mytilus edulis*) tissue (µg kg^{-1} dry weight). Vertical lines represent the range between maximum and minimum data.

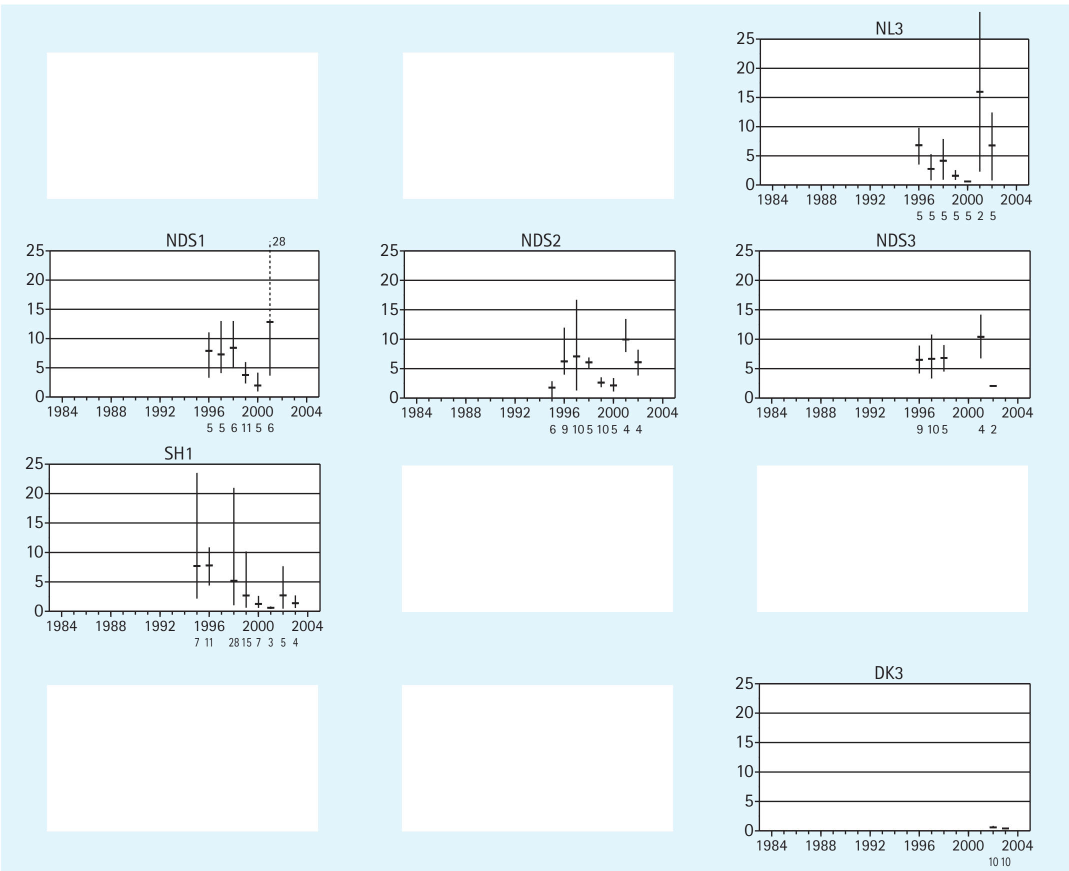


Figure 4.3.7: Average Lindane (γ-HCH) contents of flounder (*Platichthys flesus*) liver tissue (µg kg^{-1} wet weight). Vertical lines represent the range between maximum and minimum data.

4.3.3.3 Concentrations in flounder liver

Lindane contents of flounder liver (Figure 4.3.7) have been rather variable. Only in subarea SH1 did a distinct downward trend occur between 1994 and 2003, reaching a 80% decrease. In 2002, levels were highest in subareas NL3 to NDS3. In subarea DK3 the Lindane levels were a factor 10 lower than in subareas NL3 to NDS3.

The firm ecotoxicological assessment criterion (EAC) (OSPAR, 2004) was exceeded for certain length classes of flounder in subareas NL3 (2002, up to factor 2), NDS1 (2001, up to factor 7) and NDS2 (2002, up to factor ~2). If β-HCH is included, subarea NL3 exceeded the EAC in 2002 by a factor of 4.

4.3.3.4 Concentrations in bird eggs

Between 1991 and 2003, concentrations of Lindane in eggs of the common tern and oystercatcher showed a steady decrease in most subareas of the Wadden Sea. An intermediate peak appeared in the Elbe area between 1998 and 2002. In subarea NL3, however, Lindane concentrations in eggs of the oystercatcher increased significantly since 1998 (see chapter 4.5).

The geographical distribution of Lindane concentrations is similar for eggs of both bird species. In 2002, the western Dutch Wadden Sea (NL1) showed elevated levels, which were twice as high as in the eastern Dutch Wadden Sea (NL2), Ems-Dollard (NL3), Niedersachsen (NDS1) and the Danish Wadden Sea (DK1, DK3). Peak levels were found in the Elbe area (SH1, SH2 and SH3), about 4-5 times higher than in the low-level areas. In the northern Wadden Sea, the oystercatcher eggs in 2002 showed a gradient of decreasing concentrations from Elbe (SH1; ca. 8 μg·kg^{-1} fresh weight) to Skallingen (DK3; ca. 3 μg·kg^{-1} fresh weight).

4.3.4 DDT, DDD, DDE

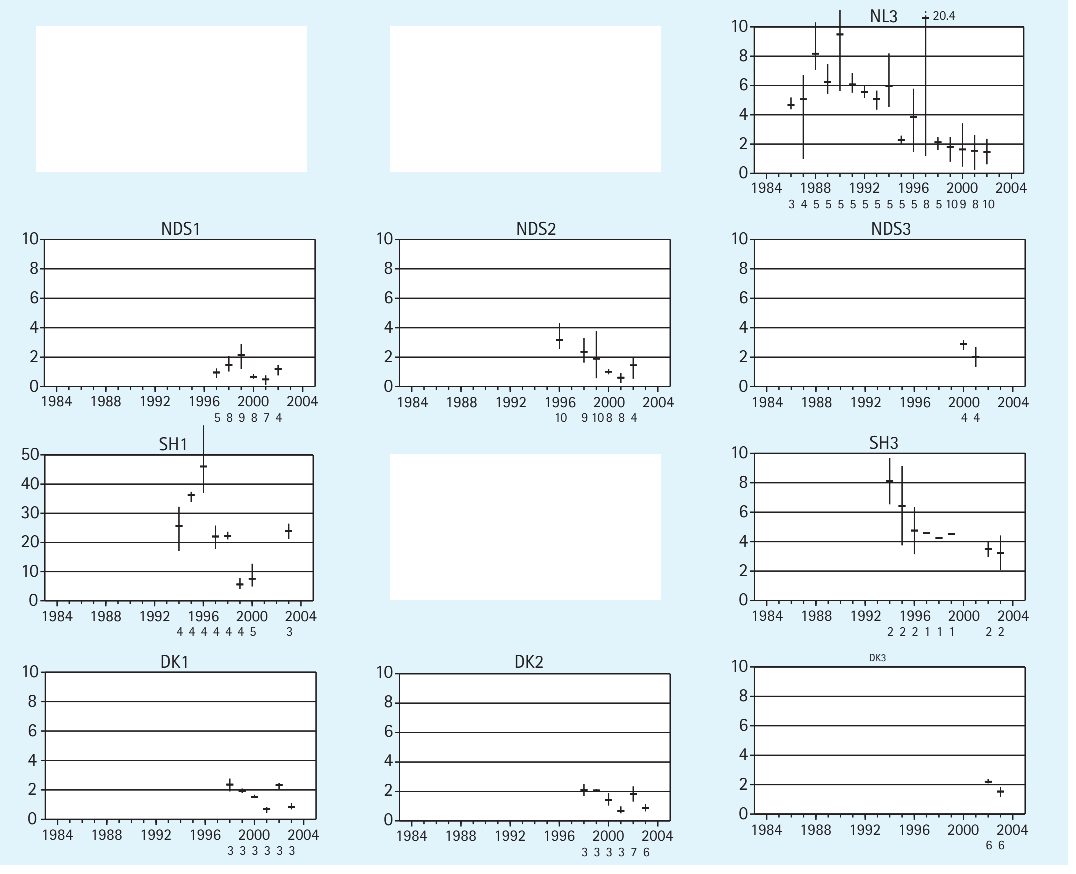
4.3.4.1 Input

Dichlorodiphenyldichloroethylene (DDE), as the end product of DTT breakdown, primarily accumulates in the environment at higher trophic levels, such as in humans (Polder *et al.*, 2002; WWF, 2004). The DDT/DDE ratio in humans was typically around 0.14 and is decreasing, indicating a reduced DDT input in the environment. These compounds were not addressed in the 1999 QSR.

4.3.4.2 Concentrations in blue mussel

In subarea NL3, concentrations of DDT (not shown), DDD (Figure 4.3.8), and to a lesser extent also of DDE (not shown), showed a 75% decrease between

Figure 4.3.8: Average DDD contents of blue mussel (*Mytilus edulis*) tissue (μg kg^{-1} dry weight). Vertical lines represent the range between maximum and minimum data.



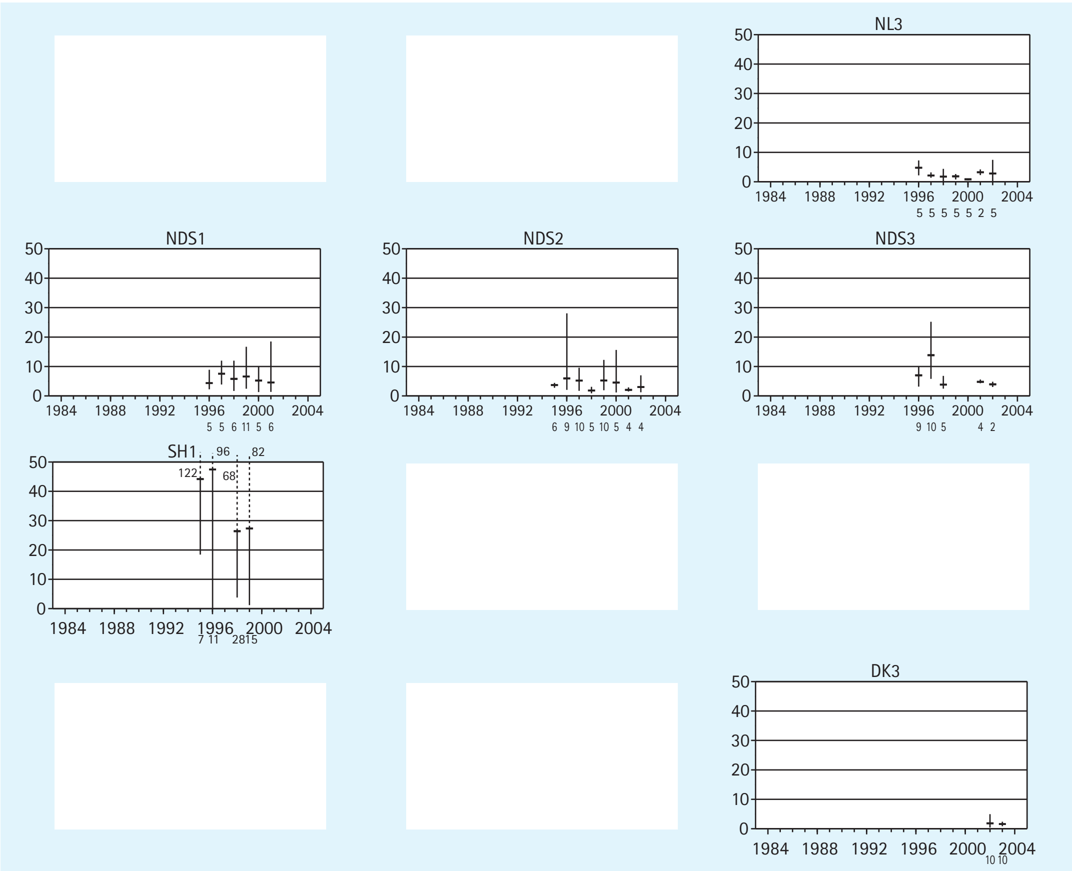


Figure 4.3.9: Average DDD contents of flounder (*Platichthys flesus*) liver tissue (µg kg^{-1} wet weight). Vertical lines represent the range between maximum and minimum data.

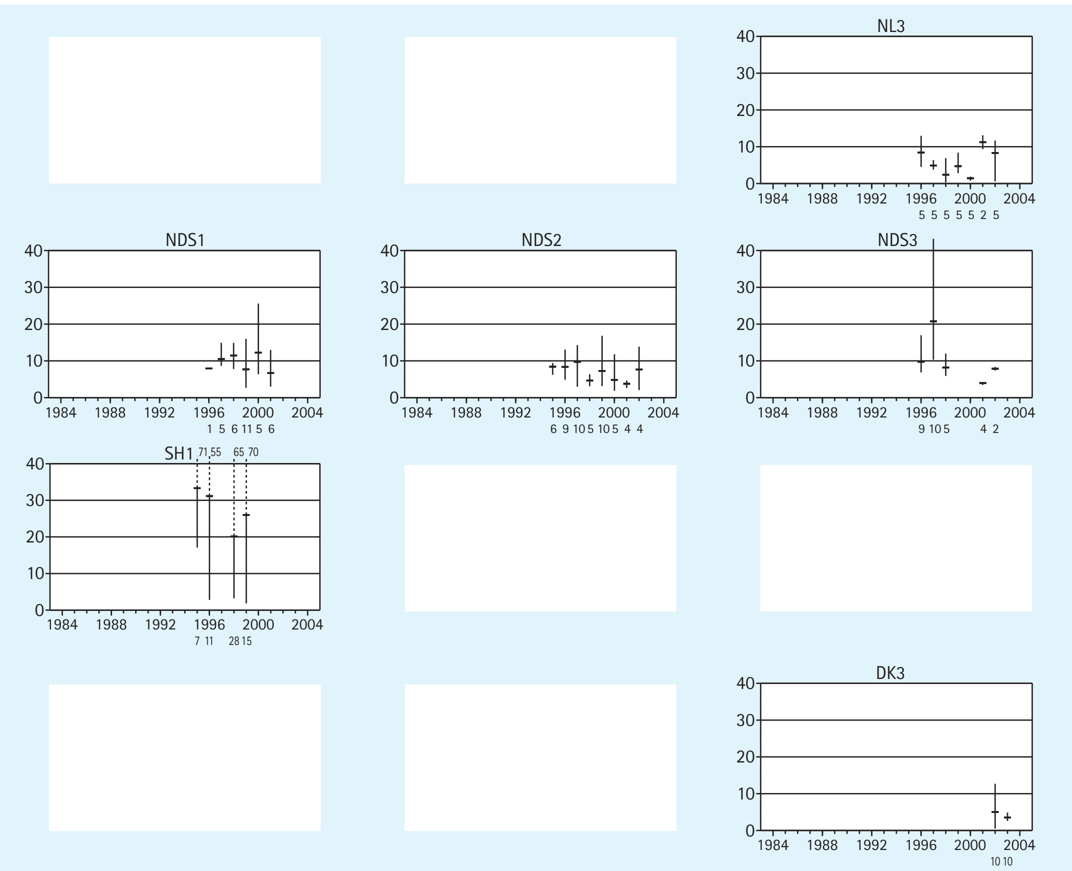


Figure 4.3.10: Average DDE contents of flounder (*Platichthys flesus*) liver tissue (µg kg^{-1} wet weight). Vertical lines represent the range between maximum and minimum data.

1988 and 2002. The shorter time series of other subareas showed the same trend (*e.g.* SH3).

DDE levels are typically twice as high as the DDT and DDD levels. ΣDDTs (sum of DDT, DDD, DDE) is relatively high in subareas NL3, SH1 and SH3.

The Elbe flood (2002) caused the DDD and DDE levels in blue mussels in SH1 to increase by a factor of 3 in 2003. DDT levels did not increase, which indicates that the Elbe flood primarily caused mobilization of historical contamination. This is in accordance with the observed increase of concentrations of DDD and DDE in Elbe suspended matter in August 2002 (CWSS, 2002).

4.3.4.3 Concentrations in flounder liver

In subareas NDS2 and SH1, high and variable DDT levels were recorded. The source of the high concentrations in subarea NDS2 may be of unknown local origin. In subarea SH1, generally high concentration occurred, particularly of DDD (Figure 4.3.9) and DDE (Figure 4.3.10). In subareas NDS2 (only DDT) and SH1 (ΣDDTs) concentration levels are up to a factor 6 higher than in other subareas of the Wadden Sea.

No data is available to check for Elbe flood (2002) related anomalies in concentrations in flounder liver.

4.3.5 Hexachlorobenzene (HCB)

4.3.5.1 Input

HCB (hexachlorobenzene) was widely used as a pesticide and in synthesis processes until it was banned in most open applications in 1988. HCB, however, is still a by-product of the production of chlorinated organic solvents, though strictly regulated. HCB is highly persistent and bioaccumulative. HCB levels found in human blood are amongst the highest of organochlorines together with DDE (metabolite of DDT), β-HCH and PCBs (WWF, 2004).

QSR 1999

HCB, used as biocide in wood conservation and crop protection, is widely present in the biosphere. Its highly volatile, bioaccumulative and persistent properties made it a 'black list' compound. In the Ems-Dollard (NL3) and Elbe (SH1, SH2) subareas relatively high concentrations were found in sediments, blue mussels and eggs of the common tern and oystercatcher. While the Ems generally showed a downward trend, there was an increasing trend in the Elbe region towards the end of the evaluation period.

Common tern eggs showed bioaccumulation levels higher than oystercatcher eggs, which in line with the HCB properties and the higher trophic level of the fish eating com-

4.3.5.2 Concentrations in sediment

The average HCB content in sediments decreased in NL1 – NL3 between 1988 and 2002 (Figure 4.3.11). Though not significant, it constitutes a 50% reduction.

HCB contents in sediments in DK1 to DK3 are at the lowest levels of NL1, but show large variations coinciding with low organic carbon contents of the sediment.

4.3.5.3 Concentrations in blue mussel

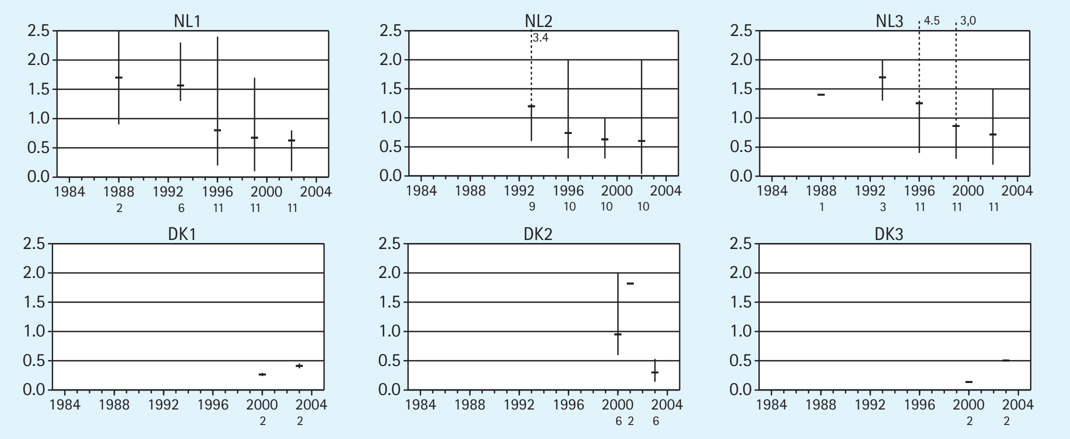
Subareas NL3 and SH1, which were 'hot spot' areas in the 1999 QSR, showed a concentration reduction of over 90% (NL3, 1988-2002) and 80% (NDS1, 1997-2002; SH1, 1996-2000) (Figure 4.3.12). In subarea SH1, the Elbe flood of 2002 may have caused the blue mussel levels to increase by a factor of 3 in 2003.

HCB levels in blue mussels are higher in subareas NDS3 (factor 7), SH1 and SH3 (both factor 3) as compared to other subareas of the Wadden Sea. This may be related to residual south to north transport along the North Sea coast of historical (as in NL3 and SH1) or recent local sources.

4.3.5.4 Concentrations in flounder liver

As in blue mussels, HCB levels in flounder liver were very high in subareas NL3 and SH1 (Figure

Figure 4.3.11: HCB contents of sediment (μg kg^{-1} at 5% organic carbon). Vertical lines represent the range between maximum and minimum data.



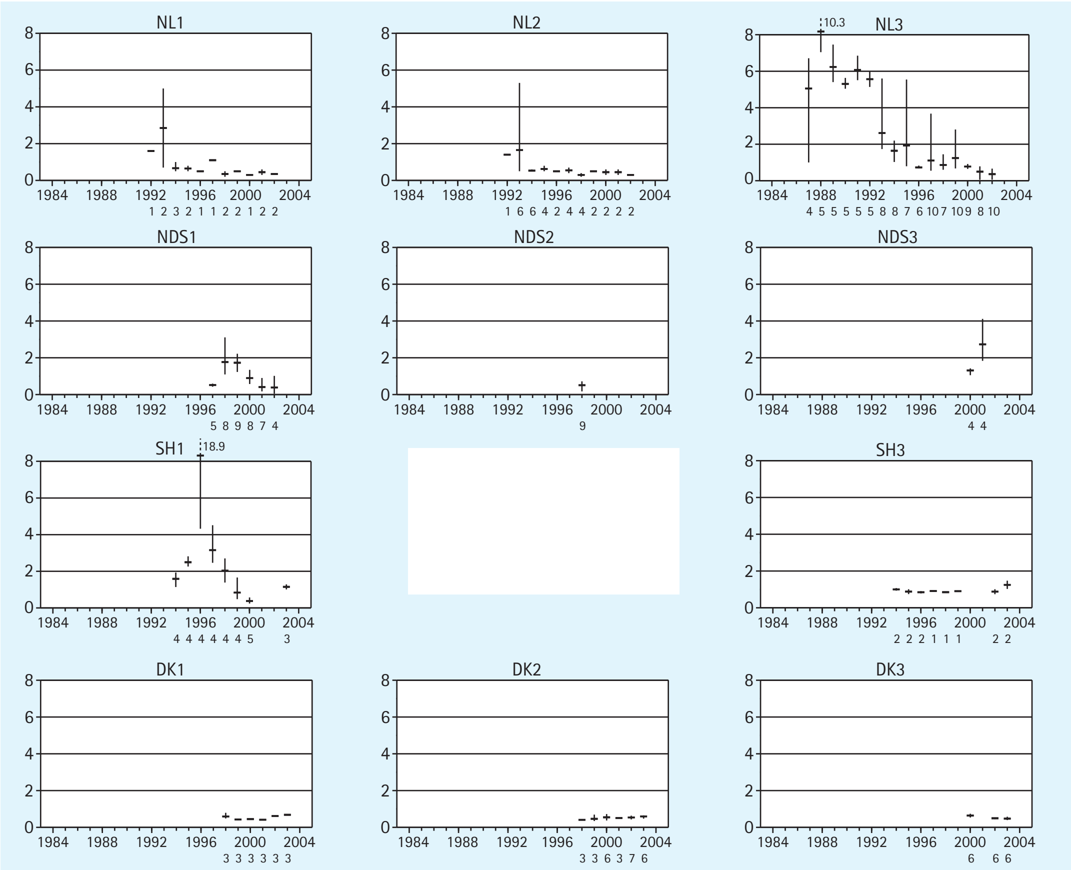


Figure 4.3.12: Average HCB contents of blue mussel (*Mytilus edulis*) tissue (µg kg^{-1} dry weight). Vertical lines represent the range between maximum and minimum data.

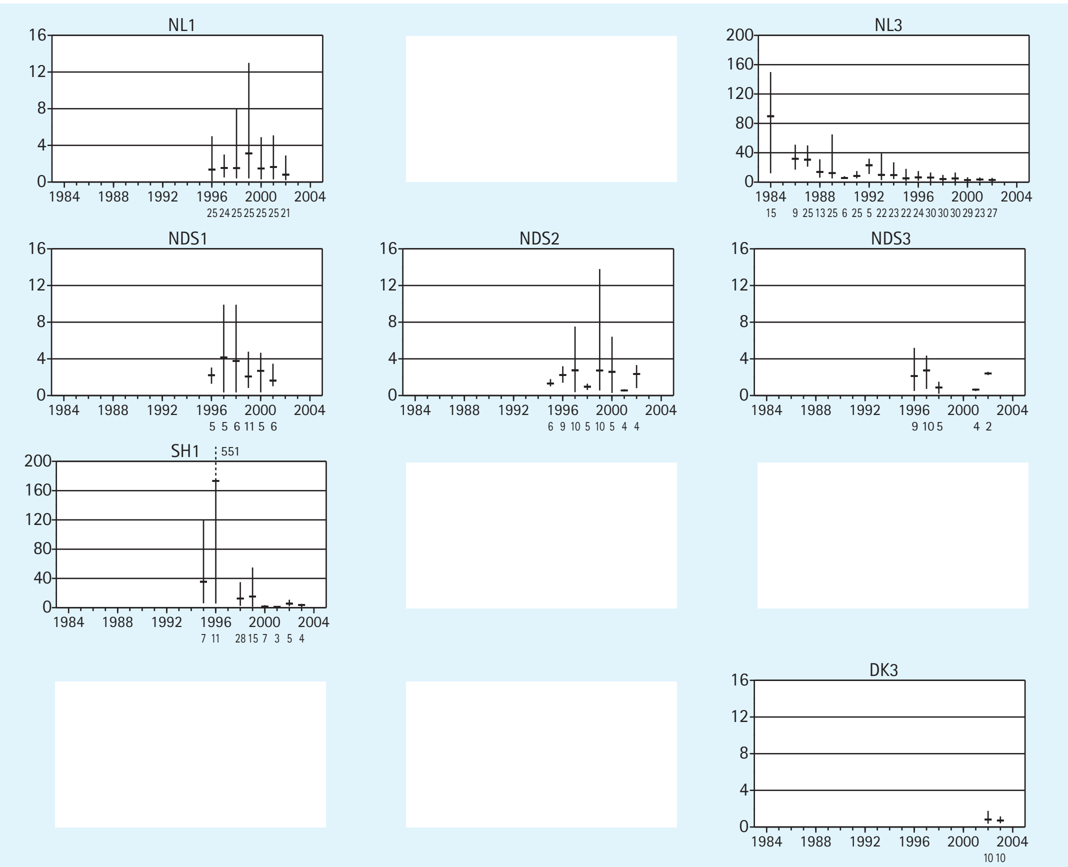


Figure 4.3.13: Average HCB contents of flounder (*Platichthys flesus*) liver tissue (µg kg^{-1} wet weight). Vertical lines represent the range between maximum and minimum data.

4.3.13). In subarea NL3, a 96% reduction of HCB concentrations was recorded between 1984 and 2002, after sanitization of the local source in the Ems estuary in 1985. A similar reduction was achieved in SH1 between 1995 and 2001. The Elbe flood of August 2002 caused increased HCB levels (by a factor of 5) already in autumn of that year (flounders were sampled in October), decreasing again in 2003.

In subarea DK3, HCB levels in flounder liver are a factor 4 lower than in subareas NL1 SH1, suggesting contamination of the entire south-western Wadden Sea by historical sources.

4.3.5.5 Concentrations in bird eggs

Trends in HCB concentrations in eggs of the oystercatcher and common tern are described in chapter 4.5. HCB concentrations in oystercatcher eggs at Delfzijl (NL3) showed a decrease of approx. 80% between 2001 and 2003.

4.3.6 Organotin compounds (TBT, TPT)

Tributyltin (TBT) acts as a hormone disruptor, causing molluscs to develop female sterility (imposex), finally leading to the extinction of the population. For further information see section 4.7.1.

Triphenyltin (TPT) compounds were not addressed in the 1999 QSR. TPT is mainly applied as biocide for potato crops, and is as toxic as TBT.

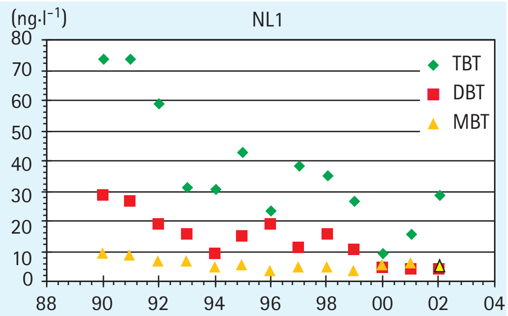
QSR 1999

Tributyltin compounds (usually applied as TBT-oxide or TBT-chloride) were extensively used in antifouling and stabilizer applications. The marine source is mainly from ships. TBT accumulates in sediments and biota. Highest concentrations were found in marinas, up to 100 fold the levels in more remote reference areas. Intercomparison between Wadden Sea regions was hampered because of methodological differences in both sampling and analysis.

4.3.6.1 Inputs

No input data is available from monitoring. Models have been developed to estimate leaching out of applications (in: Bellert *et al.*, 2004).

Figure 4.3.14: Butyltin compounds in water (ng l^{-1}) of marinas in the Dutch Wadden Sea.



Organic tin compounds have been extensively monitored in The Netherlands. Some results will be shown.

4.3.6.2 Concentrations in water

Buty Itin compounds have been monitored mainly in marinas. In the western Dutch Wadden Sea (NL1), concentrations of TBT and its metabolites showed a strong decrease between 1990 and 2002 (Figure 4.3.14). Most prominent was the 60% reduction of TBT in 1993, the year that use of TBT in anti-fouling paints on ships <25 m was banned (see Eltink, 2004).

In 2002 the high firm ecotoxicological assessment criterion (OSPAR, 1997) was exceeded by a factor of 300 in the marinas of the Dutch Wadden Sea (NL2).

4.3.6.3 Concentrations in sediment and suspended matter

In the Dutch Wadden Sea, butyl and phenyl tin compounds have been monitored in suspended matter (SPM, 3 samples per year) as well as in sediment (once every 3 years). TBT was generally dominant in estuarine and marine sediments, except for one location close to shipyards building sea-going vessels (Bellert and van den Ven, 2003). TPT levels were dominant in fresh-water sediments, and were very high in agricultural (potato crop) areas (Bellert and van den Ven, 2003). Concentrations in SPM are in the same range as in sediment. As an example, in figure 4.3.15 data series are shown for butyl and phenyl tin compounds in SPM in subarea NL3. Taking August and November concentrations, normalized to 5% organic carbon, a downward trend can be observed from approx. 2001 onwards, especially for TBT.

At all locations in the Dutch Wadden Sea, TBT constitutes ~60% of all butyl tin compounds. The data for 1998-2002 indicates a dominance of TPT in the Phenyl tin compounds of 40-70%. By 2003 the dominance of TPT was reduced to ~20%, whereas DPT makes up 50%. This probably indicates a decrease in source related input of TPT and a more persistent behavior of its metabolites.

In 2002, the high provisional ecotoxicological assessment criterion (OSPAR, 2004) was exceeded by a factor of 400 in sediments of the Dutch Wadden Sea (NL1 to NL3).

4.3.6.4 Concentrations in blue mussel

Organotins in blue mussel are dominated by TBT (Figure 4.3.16), with concentrations of ~250 µg kg^{-1} dry weight in subarea NL3 and 150 µg kg^{-1} dry weight in NL2 over the period 1999-2002. The concentrations of the metabolites DBT and MBT are much lower: at ~20 to 5 % level, respectively.

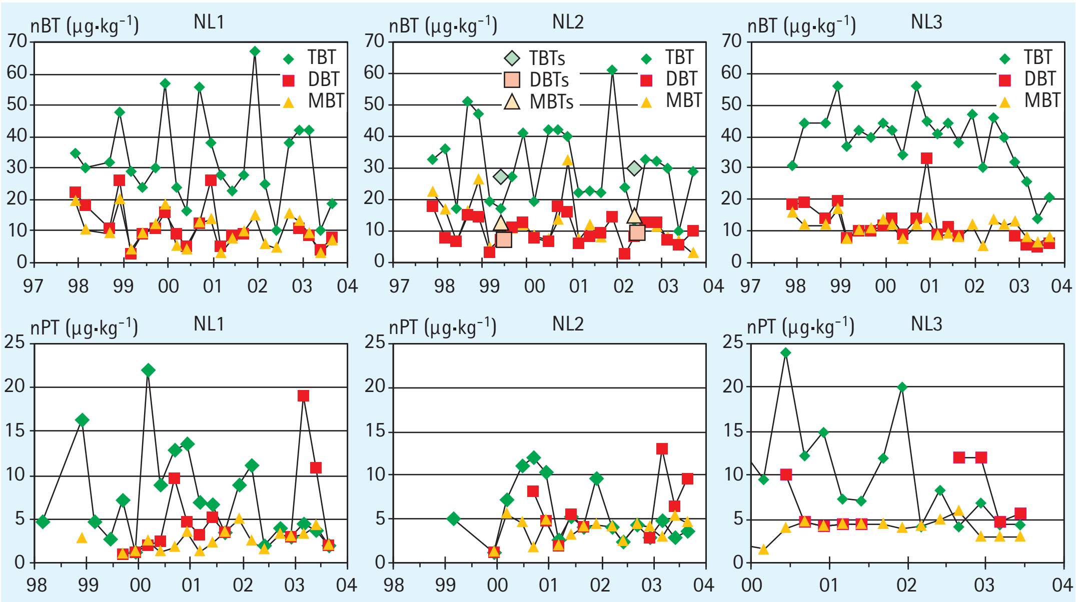


Figure 4.3.15: Average organic tin contents of sediment in fraction <63 µm (µg kg^{-1} dry weight). nBT graph NL2: TBTs/DBTs/MBTs: concentrations in sediment. Vertical line represent the range between maximum and minimum data. nBT: butyltins, nPT: phenyltins.

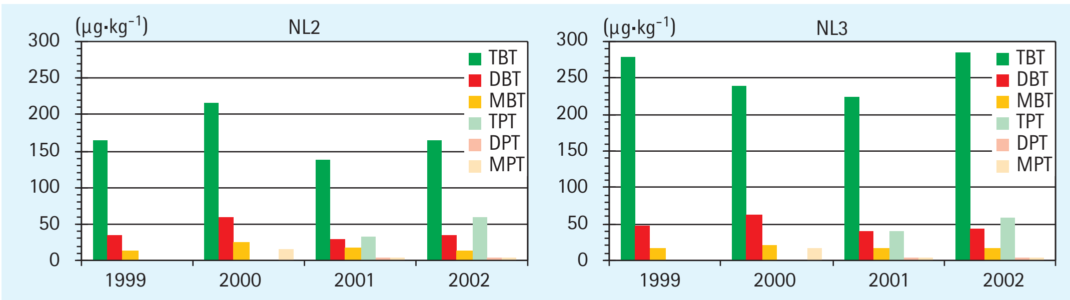


Figure 4.3.16: Average organic tin contents of blue mussel (*Mytilus edulis*) tissue (µg kg^{-1} dry weight). TBT, DBT, MBT = Tri-, Di-, Monobutyltin. TPT, DPT, MPT = tri-, di-, monophenyltin.

Similarly, TPT is dominant above its metabolites DPT and MPT. This data indicates a selective accumulation of TBT by blue mussels, which is likely to be reflected in butyl tin concentrations in the common eider (see below).

In 2002, the high firm ecotoxicological assessment criterion (OSPAR, 2004) was exceeded by a factor of 15 in subarea NL2 and a factor of 25 in NL3.

Figure 4.3.17 shows TBT and TPT concentrations in blue mussels in the German Wadden Sea (Jade Bight, NDS2) for the time period 1985-1999. TPT concentrations are decreasing after a phase out of its use as antifouling paint in the mid 1980s. TBT concentrations remain unchanged (about 200 µg kg^{-1} dry weight in the period 1995-1999) even after the EU-ban for use as antifouling paint in small ships in 1991 (Rüdel *et al.*, 2003).

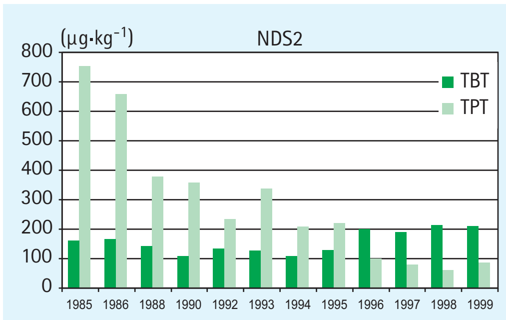


Figure 4.3.17: Concentration (µg kg^{-1} dry weight) of organic tin compounds in blue mussels (*Mytilus edulis*). TBT: Tributyltin. TPT: Triphenyltin (source: Rüdel *et al.*, 2003).

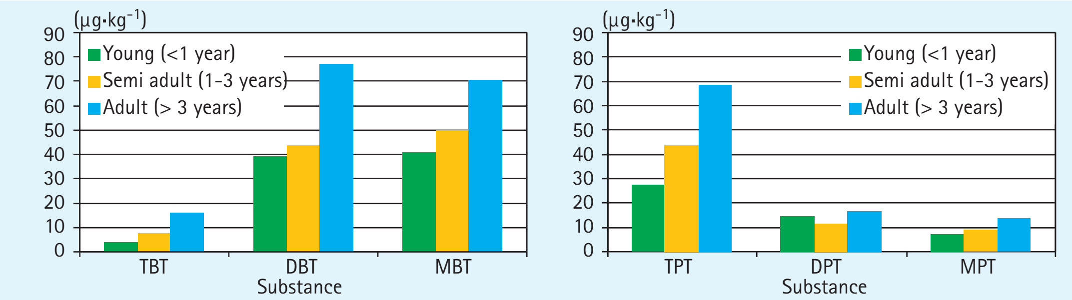


Figure 4.3.18: Concentration (µg kg^{-1} dry weight) of organic tin compounds in liver of the harbour seal (*Phoca vitulina*) found dead in 2000. Dibutyltin (DBT) and monobutyltin (MBT) are TBT metabolites. Diphenyltin (DPT) and monophenyltin (MPT) are TPT metabolites. Accumulation of butyltins and triphenyltin (TPT) increases with age, (source: Eltink, 2004).

4.3.6.5 Concentrations in harbour seal and common eider

Dead harbour seals, stranded on the Dutch Wadden Sea and North Sea shores during the PDV-epidemic of 2002, were collected and their livers were analyzed for organotins. The results show that TBT was metabolized to DBT and MBT, the latter being present in higher concentrations than TBT. Concentrations were age-dependent (Figure 4.3.18).

In contrast, triphenyltin (TPT) was not as easily metabolized as TBT, as shown by high concentrations in the liver relative to TBT (70 and 15 µg kg^{-1} respectively in adults). Considering the similar toxicity of TBT and TPT and the assumed lower toxicity of their metabolites, TPT poses a higher environmental risk to seals than TBT. A roughly estimated daily intake of organotins of ~8 µg kg^{-1} body weight was considered too low to reach the level of Ah-receptor inhibition (1000 µg kg^{-1} body weight) described by Vos *et al.* (2003).

In the livers of common eider, found dead in the winters of 1999 and 2000, extremely high DBT concentrations were found, whereas TBT and MBT represented only ~4% of the total butyltin content (Figure 4.3.19). Concentrations of phenyltin compounds were lower (20–25% of the butyltin compounds) with TPT and DPT as the major constituents, representing 38% and 31% respectively of the phenyltins. This data suggests that TBT in blue mussels, the primary food source of the common eider, is transferred to the bird and readily metabolized and detoxified to DBT, reaching levels 10-fold of those in blue mussels. It still needs to be clarified whether the largely enhanced levels of TBT-metabolites, though less toxic, exert negative effects on the biota of the Wadden Sea.

Phenyltin levels in blue mussels are at about 10% of butyltins. TPT is relatively persistent in blue mussel, which was also noted for harbours seal.

In conclusion, it appears that biomagnification of organotin compounds occurs primarily in birds (common eider) and to a lesser extent in marine mammals (harbour seal). Such biomagnification in lung-breathing organisms, as opposed to gill-breathing animals, was also reported for brominated flame retardants (Boon *et al.*, 2002).

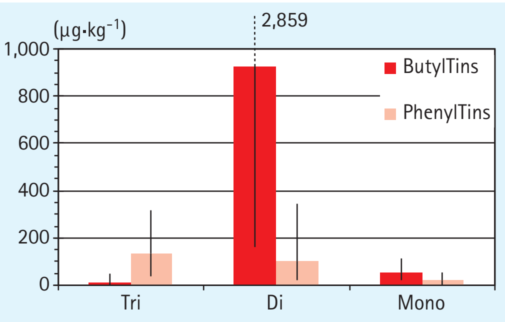


Figure 4.3.19: Average (bars) and minimum/maximum (vertical lines) concentration of organic tin compounds (µg kg^{-1} dry weight) in liver tissue of common eider (*Somateria mollissima*) (N = 12) found dead in the winter of 1999 and 2000. The di- and monobutyl and phenyltins are metabolites of tributyltin (TBT) and triphenyltin (TPT), respectively (source: Werkman *et al.*, 2000).

4.3.7 Pesticides

QSR 1999

Regular monitoring of pesticides (except Lindane, HCB) in the Wadden Sea area was absent. Dutch and German pesticide surveys (1990-1996) showed the presence of a large variety of pesticides , whereas this was not expected on the basis of biodegradation tests. The most frequently detected compound groups belong to the organic phosphates, triazines (and derivates), and phenylurea herbicides. Herbicide concentrations were found at levels potentially harmful to eelgrass (*Zostera marina*).

A large series of polar pesticides (Atrazine, Chloorfenvinfos, Chloroprofam, Chlorotoluron, Diuron, Irgarol-1051, Isoproturon, Linuron, Methabenzthiazuron, Metolachlor, Pirimicarb, Propoxur, Simazine, Terbutryne, Terbutylazine, Methyl-tolclofos) has been monitored in Dutch Wadden Sea water since 1997 (atrazines) or 2002. Frederiks *et al.* (2004) report that Chlortoluron, Diuron, Isoprouron, Irgarol, Metolachlor, Propoxur, Terbutryne and Terbutylazine exceed the target levels set by the Dutch policy (MinVenW, 1998).

4.3.8 Summary of trends

The persistency of most xenobiotics presents the largest problem in reaching the goal of downward trends of concentrations in the sediment and biota of the Wadden Sea. This was shown by the residual south to north transport into the Wadden Sea and the risk of remobilization from old deposits as shown by the Elbe flood in 2002.

Most of the 'old' xenobiotics are still present in the Wadden Sea environment, but show a continuing downward trend. The relatively 'new' xenobiotics such as organotin compounds may have started to decrease slightly, but are still bioaccumulating. Their chronic effects on birds and marine mammals need to be clarified.

PCBs are still wide-spread, but concentrations have decreased considerably over the past 20 years. They still, however, exceed agreed background levels by many times.

Lindane and its metabolites are mostly decreasing, though β-HCH is persistent in the higher trophic levels.

In the Wadden Sea, elevated levels of DDT and DDE in subareas NL3, SH1 and SH3 further decreased in the 1990s. The Elbe flood of 2002 caused an increase of levels in blue mussel in subarea SH1.

HCB decreased in all subareas of the Wadden Sea, with a relatively late response in the higher trophic level (bird eggs).

Organotin compounds in the water of Dutch marinas decreased between 1990 and 2002 by about 60%. Since 2002, concentrations in particulate suspended matter also decreased. The share of the primary compound TPT in the total of phenyl tin compounds decreased recently, indicating a reduction in input of TPT.

The Targets for xenobiotics are difficult to assess, because no values have been attached to 'concentrations ...as resulting from zero discharges'. When in the course of time concentrations do not continue to show decreasing trends, this may in practice be considered as having reached the target.

With regard to PCBs, the maximum levels in sediment (NL1), and liver tissue of adult flounder exceeded the OSPAR ecotoxicological assessment criteria.

For Lindane, the OSPAR ecotoxicological assessment criteria are exceeded in liver tissue of flounder in subareas NL3, NDS1 and NDS2.

For TBT the OSPAR ecotoxicological assessment criteria are exceeded in water, sediment and mussels in NL1 to NL3 by a large factors. It is likely, however, that most if not all Wadden Sea subareas exceed these OSPAR criteria. Relevant data, however, was not readily available.

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4.4 Oil Pollution and Seabirds

Kees (C.J.) Camphuysen
David M. Fleet
Bettina Reineking
Henrik Skov

4.4.1 Introduction

Oiled seabirds washing ashore, dead or alive, have had a signalling function since the very early days of oil pollution at sea. The number of dead oiled seabirds on the coastline is not in itself a reliable parameter for monitoring changes in oil pollution at sea. The percentage of birds that is oil contaminated among the birds found washed ashore (called the 'oil rate'), however, has proven to be a useful monitoring tool (Camphuysen and Franeker, 1992; Stowe, 1982; Vauk *et al.*, 1989). Differences in oil rates between sea areas have clearly indicated that chronic oil pollution was more intense around shipping lanes than elsewhere. In recent years, beached bird survey techniques have been further refined and species-specific oil-rates were introduced as the main instrument to measure trends in chronic oil pollution at sea (Camphuysen and Franeker, 1992; Camphuysen and Heubeck, 2001).

4.4.1.1 Ecological importance

Chronic oil pollution is a constant threat to seabirds and other marine life. Oiled seabirds are the most visible and obvious casualties resulting from oil spills, but the sensitivity to oil of other marine organisms and coastal habitats is enormous (Baker, 1983; Bergman, 1985; Kingston, 1992). This is particularly true for soft-sediment environments, such as the Wadden Sea, and attempts to minimize oil pollution in this area were initiated long ago. However, the most important sources of chronic oil pollution in terms of casualties among seabirds are typically situated offshore, such as shipping and offshore oil and gas exploration (Dahlman *et al.*, 1994). Tens of thousands of seabirds are known to wash ashore oiled each winter in the southern North Sea alone (Camphuysen, 1989), but as yet it has been difficult to demonstrate effects in terms of major population declines. There are various explanations for this, one of which is the lack of adequate data (age composition of casualties and information on breeding origin; Heubeck *et al.*, 2003), but of greater significance is probably the overall success of seabirds due to, for example, shifts in prey availability due to the overfishing of predatory fish (Camphuysen and Garthe, 2000).

4.4.1.2 Conclusions of the 1999 QSR

Oil pollution of the seas was recognized as a problem in the first half of the 20th century and both national and international regulations to control discharges of oil were introduced. The introduction of MARPOL 73/78 (International Convention for the Prevention of Marine Pollution from Ships) was eagerly awaited, but as reported in the 1999 QSR, investigations had not provided evidence for a sudden improvement since Annex I (Regulation for the Prevention of Pollution by Oil) of this Convention came into effect in 1983. At the same time, however, and partly contrary to observations during aerial surveys where no significant trends could be found, declining oil rates among beached birds were seen as a clear sign that the situation was improving (Camphuysen, 1998; summarized in the 1999 QSR). Yet, it was concluded that despite these apparent declines, oil rates were still very high, particularly for pelagic seabirds of the North Sea. Within the Wadden Sea, the decline was most prominent, and this was seen as a positive effect of joint efforts to clear this area from chronic pollution by extensive surveillance of near-shore waters and consistent clean-up operations when the Wadden Sea became under threat by localized spills.

4.4.2 Policy

4.4.2.1 Trilateral policies

Shipping activities are a continuous source of contamination of the marine environment with oil, garbage and hazardous substances (de Jong *et al.*, 1999). Information on temporal changes and spatial differences in the oil pollution of the marine environment is being provided by Beached Bird Surveys carried out according to standardized methods and on a long-term basis. Trilateral policies for the reduction of pollution from ships were agreed at the Ministerial Conferences in Stade 1997 (Trilateral policy and management, §2.1.3-5) and in Esbjerg 2001 (Esbjerg Declaration: shore reception facilities §54-56, impacts of shipping §57-62, PSSA Wadden Sea §63-66). The aim of all these measures was the elimination of operational oil pollution, combating illegal discharges and minimizing accidental pollution by oil from shipping.

4.4.2.2 'Special Area' concept

A new and important feature of the MARPOL Convention was the concept of Special Areas (regarding oil MARPOL Annex I). These areas are considered so vulnerable to pollution by oil that oil discharges within them have been completely prohibited, with only minor and well-defined exceptions. The 1973 Convention identified the Mediterranean, the Black Sea, the Baltic Sea, the Red Sea and the Gulf area as Special Areas. The North Sea was excluded, despite its fisheries, rich wildlife and its status as one of the most polluted sea areas in the world (Couper, 1983). This was altered in September 1997 with the adoption of the

1997 amendment that came into force on 1 February 1999: North West European waters were designated a Special Area under MARPOL Annex I. This region covers the North Sea and its approaches (including the Wadden Sea), the Irish Sea and its approaches, the Celtic Sea, the English Channel and its approaches and part of the North East Atlantic immediately to the West of Ireland. In Special Areas, discharge into the sea of oil or oily mixtures from any oil tanker and ship over 400 t is prohibited. The expectations from this step are considerable, because the amounts of oil that are allowed to be spilled at sea in Special Areas are so small that oiled seabirds should not occur, except in occasional oil incidents. Obviously, the declaration of a Special Area status is just one step. Intensified or at least continuous control through aerial surveillance and harbor inspections is required to prosecute offenders and to bring illegal discharges down to acceptable levels.

4.4.2.3 PSSA Wadden Sea

In 2002, following a joint application of Denmark, Germany and The Netherlands, the Wadden Sea was designated as a Particularly Sensitive Sea Area (PSSA) by the International Maritime Organization (IMO) (Reineking, 2002). A PSSA is an area that needs special protection because of its significance for recognized ecological or socio-economic or scientific reasons. In addition, the area should be at risk from international shipping activities. The designated PSSA Wadden Sea is the marine area of the Wadden Sea Conservation Area, comprising the Wadden Sea national parks in Germany and the Wadden Sea nature protection areas in Denmark and The Netherlands. The major shipping routes have been excluded from the PSSA. The PSSA Wadden Sea designation will send strong signals to the international shipping community and increase awareness of the particular sensitivity of the area to impacts from shipping, such as oil.

4.4.3 Sources of pollution

Chronic oil pollution is not only restricted to mineral oil, but in fact, numerous lipophilic substances are involved, including mineral oil, while few studies were capable of discriminating between types. While incidents with non-mineral oils are known to occur (Camphuysen *et al.*, 1999), and adverse effects are well known (Bommelé, 1991), the scale and trends in levels of non-mineral oil pollutants in the marine environment are very uncertain (Timm and Dahlmann, 1991; Hak, 2003).

With regard to mineral oil pollution within the North Sea area, there is good evidence that ordinary ships' fuel oils, deliberately discharged with bilge waters, are the main source of oil pollution (Vauk *et al.*, 1987; Vauk *et al.*, 1989; Dahlmann *et al.*, 1994; Fleet and Reineking, 2000, 2001; Reineking and Fleet, 2002). Since the 1980s, when oil sampling and analysis in Germany began, fuel oil residues from shipping were identified as the main source of chronic oil pollution, accounting for nearly 90%.

Aerial surveys have shown a clustering of slicks around the major shipping lanes in the south and in the south-east (Directie Noordzee, 1995, 2001; Schallier *et al.*, 1996; von Viehbahn, 2001). Figure 4.4.1 shows the high concentrations of oil pollution especially in the area with intensive sea traffic (traffic separation scheme) off the coast of The Netherlands, but also off the coast of the North

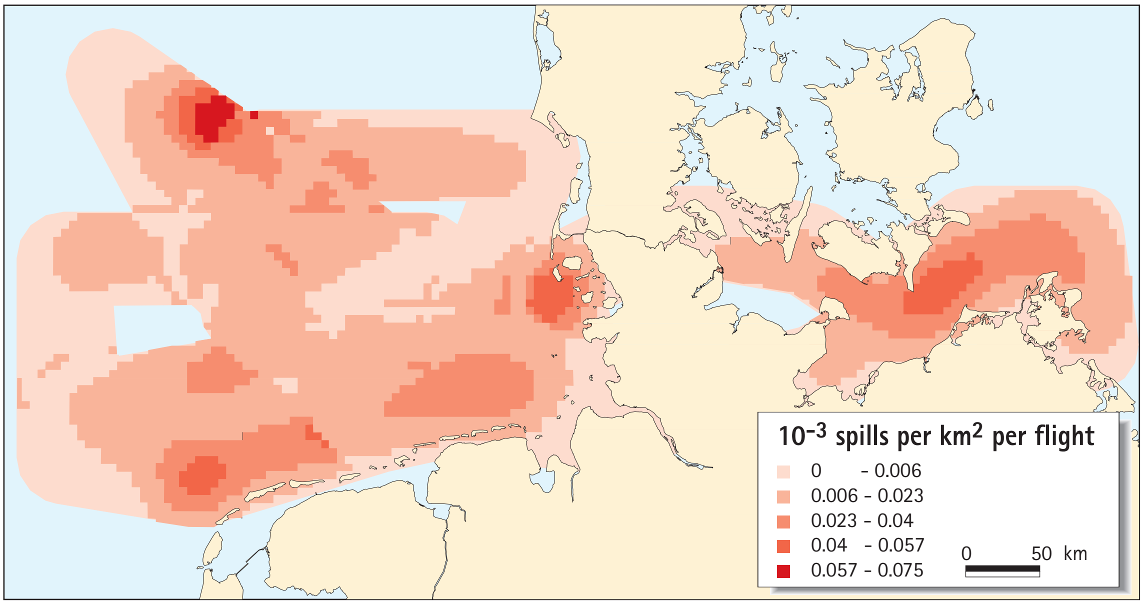

Figure 4.4.1: Standardized density of oil spills in the period 1989–1998 for the German Bight. Source: von Viebahn, 2001.

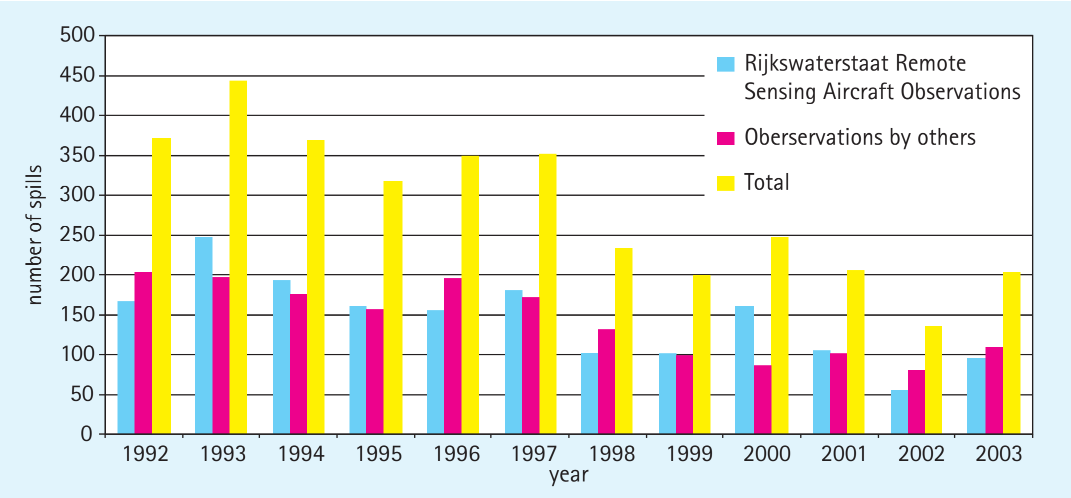

Figure 4.4.2: Reported oil spills on the Dutch Continental Shelf 1992-2003. (Data from Directoraat-Generaal Rijkswaterstaat, Directie Noordzee; data before 1992 is not reliable).

of Schleswig-Holstein. According to the reported oil spills off the Dutch and German coast (see Figures 4.4.2 and 4.4.3) there is a decline in comparison to the 1990s.

The clustering of oil slicks around the busiest shipping areas is clearly reflected in oil rates found on beach-washed bird corpses, both in the past (Stowe, 1982) and in recent years (Furness and Camphuysen, 1997; Camphuysen, 2003; Fleet and Reineking 2001). This would suggest that the main source of pollution remained the same over time. It should be stressed, however, that, with the exception of a 3.5 year study on the German coast in the period 1997-2001 (Dahlmann and Sechehaye, 2000; Fleet and Reineking, 2001), there is fairly little concrete information about the sources of pollution in recent years. Regular analysis of oil residues found on beached birds and beaches would provide an insight in any changes in source of oil pollution at sea, and would therefore show where measures for pollution control should be tightened.

4.4.4 Oiled Seabirds

Systematic beached bird surveys, organized to assess the fraction of oiled seabirds washed ashore among the total number of dead birds found on beaches (oil rate), have been intense for decades, particularly in Denmark, Germany and The Netherlands (Joensen, 1972 a,b; Joensen and Hansen, 1977; Reineking and Vauk, 1982; Averbeck *et al.*, 1993; Camphuysen, 1989, 1997; Reineking, 1997; Fleet and Reineking, 2000, 2001; Durinck and Skov, 2001; Fleet *et al.*, 2003). Earlier results indicated slow but consistent declines in oil rates over the past decades (Camphuysen, 1997, 1998; Durinck and Skov 2001; Fleet and Reineking, 2001). Nevertheless, oil rates in the Southern North Sea and in the Wadden Sea area throughout the 1980s and 1990s were regarded unacceptably high, particularly for pelagic seabirds. The enforcement of a Special Area status in 1999 should lead to further decreases in oil rates among seabirds; so far, results have not become evident.

Since the 1999 QSR, oil rates of the most com-

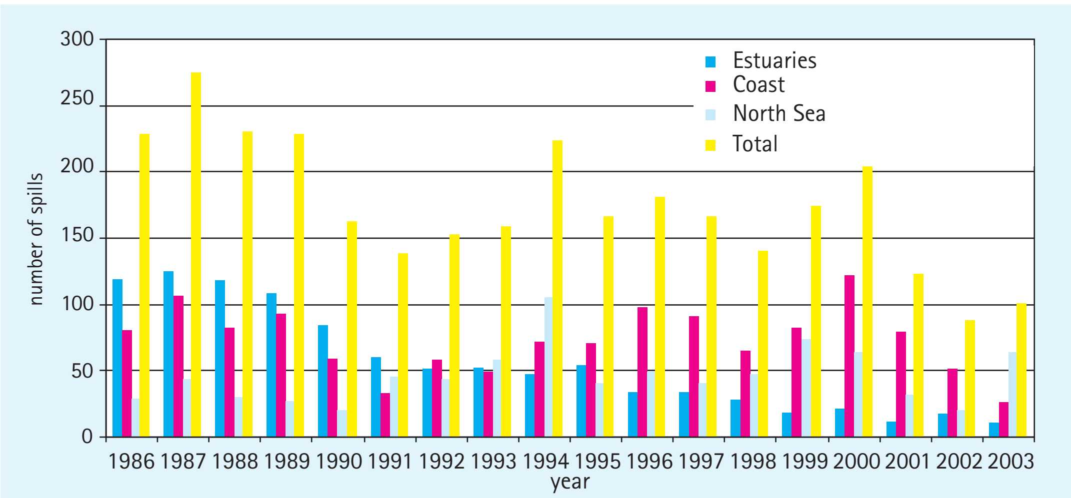

Figure 4.4.3: Reported oil spills in the German North Sea 1986-2003. (Data from the 'Maritimes Lagezentrum Havariekommando').

mon seabird found on North Sea beaches, the common guillemot *Uria aalge*, an indicator for marine oil pollution, have been proposed as one of the Ecological Quality Objectives (EcoQOs) (Camphuysen, 2004) by the Biodiversity Committee (BDC) of the OSPAR Commission. The EcoQO, as agreed by the 5th North Sea Conference, was defined as: the proportion of oiled common guillemots should be 10% or less of the total found dead or dying individuals of this species, in all areas of the North Sea. Common guillemots were chosen on the basis of their wide distribution in winter and their sheer abundance: sufficiently large samples could be obtained each winter in all North Sea countries to calculate a reliable oil rate figure. The methodology of both the surveys and the subsequent analysis of data has been described previously (Camphuysen and Dahlmann, 1995; Camphuysen and Meer, 1996; Camphuysen and Heubeck, 2001).

4.4.5 Trends in oil rates in the Wadden Sea area

In the following analysis, the Danish-German-Dutch North Sea coast has been subdivided into ten sub-regions based on the planning of surveys in each of the participating countries (Table 4.4.1). Within the sub-regions a distinction was made between (1) coast exposed to the Wadden Sea (mainland coast as well as island coast facing the mainland) and (2) coast exposed to the North Sea (on islands). The second column (DK) comprises data for the Danish Wadden and North Sea, the last column (NL mainland) includes data for the Dutch mainland coast of the North Sea south of the Wadden Sea.

For common guillemots, one conclusion can be drawn straight away: the EcoQO of 10% oiled has not yet been reached, although an overall decline in oil rates since the mid-1980s is obvious (Table 4.4.1; Figure 4.4.4). The results give a modest indication of a sharper decline since 1999, and in fact, with the exception of Germany's North Sea exposed coasts, oil rates seem to have stabilized over the most recent years at levels just below 50%. On the Schleswig-Holstein (SH) North Sea exposed coast in Germany, the average oil rate since 1999 is 34%. This is significantly lower than the average for the winters 1992/93 to 1997/98 (62%). On the North Sea exposed coast in Niedersachsen (Nds), this difference was less apparent. Nevertheless, the lowest three oil rates recorded in the period 1992/93-2002/03 in this region were measured in the last three years, with the lowest

Table 4.4.1:
Oil rates in common guillemots (% oiled of total number found) in the sub-regions in and around the Wadden Sea in winter 1984/85-2002/03. Blank cells indicate insufficient data (sample <25 individuals), or no sampling effort.
DK = Danish west coast including Wadden Sea; FRG Hel ns = Helgoland (North Sea exposed), German Bight; FRG Nds ws = Wadden Sea exposed coasts in Niedersachsen; FRG Nds ns = North Sea side of the islands in Niedersachsen; FRG SH ws = Wadden Sea exposed coasts in Schleswig-Holstein; FRG SH ns = North Sea side of the islands Schleswig-Holstein; FRG SH + Nds ws = Wadden Sea exposed German coasts; NL ws = Dutch coasts Wadden Sea exposed; NL islands = North Sea side of the Dutch Wadden Sea islands; NL mainl = Dutch North Sea coast southwards of Den Helder.
ns = North Sea exposed (coast of the islands facing the North Sea),
ws = Wadden Sea exposed (mainland coast as well as island coast exposed to the mainland).

Winter	DK	FRG Hel ns	FRG Nds ws+ns	FRG Nds ns	FRG SH ws+ns	FRG SH ns	FRG Nds+SH ws	NL ws	NL islands	NL mainl.
1983/84	78.7									
1984/85	75.8	86.6			43.3				92.3	71.0
1985/86	78.0	89.3	77.8		47.7			82.4	96.5	73.4
1986/87	90.1	92.0							90.9	80.0
1987/88	77.5	81.0			39.1			85.0	95.5	99.0
1988/89	78.4	73.7			39.4			52.7	86.7	58.0
1989/90	66.2	62.4	59.3		30.9			30.0	67.8	66.7
1990/91	74.8	58.1			21.7				62.5	84.1
1991/92	85.2	67.1	73.3		40.8				96.7	96.5
1992/93	31.1			47.8		43.4	21.4	22.2	18.4	28.1
1993/94	54.2			46.0		78.4	57.5	36.1	20.0	50.3
1994/95	71.3	85.3		65.5		72.0	35.7	46.2	33.3	47.2
1995/96				48.8					20.0	35.0
1996/97		63.3		61.0		79.6			66.7	83.3
1997/98	55.6			55.4		34.5			43.8	62.5
1998/99	43.8	41.4		25.4		24,8	26.0	3.3	27.1	25.6
1999/00	59.6	78.9		53.5		33.3	16.7	72.7	22.2	65.3
2000/01		54.8		43.1			14.3		60.0	41.7
2001/02	46.6			36.5		33.3	30.8		17.4	60.0
2002/03	56.0			29.3		36.4			60.0	98.2

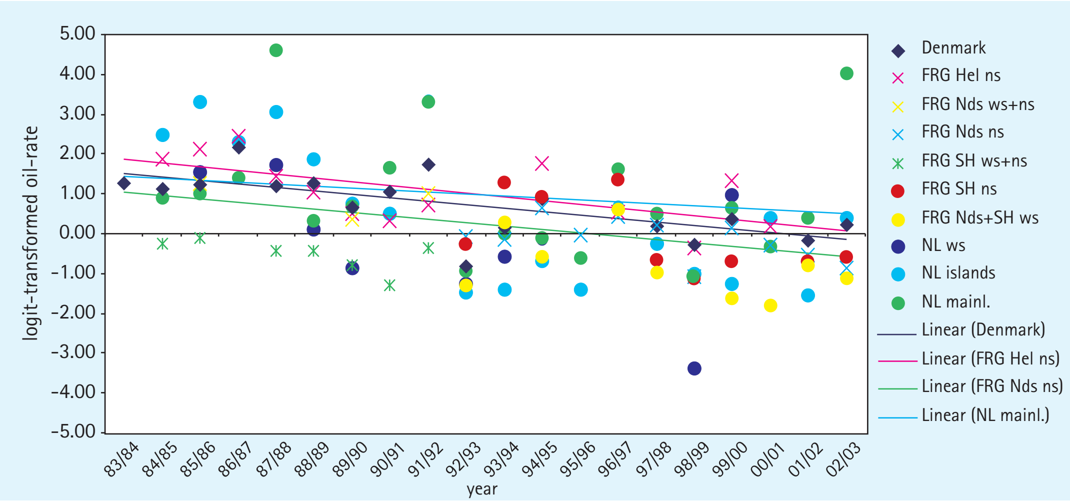

Figure 4.4.4: Logit-transformed oil rates in common guillemots in the areas around the Wadden Sea (*cf.* Table 4.4.1) and overall declining linear trends in the Dutch Wadden Sea + mainland, in Denmark, and in two areas at the German North Sea coast (Helgoland and North Sea exposed coast in Niedersachsen). Logit values of 0.0 refer to oil rates to 50%; 100% and 0% are infinitely large positive and negative values respectively.

value on record (29%) in 2002/03. Camphuysen (2003) observed a reverse trend in oil rates in pelagic seabirds in 2002/03 (Table 4.4.1), but concluded that this might have been caused by an unfortunate coincidence of oil incidents (including the 'Tricolor' in the Channel and the 'Assie Eurolink' that sank north of Terschelling). It should be noted, however, that high oil rates in common guillemots occurred again in winter 2003/04 (70%; NZG/NSO unpubl. data; not included in the present analysis), indicating that chronic oil pollution levels are still high.

Oil rates fluctuate from year to year, and where oil incidents or significant local spills may raise oil rates, natural mortality events have a tendency to lower the values found. These fluctuations introduce some noise in the signal received, but we chose not to arbitrarily remove values from the time series, but rather to work with the variability in the material as it was found. It is very interesting to note that several of the more drastic variations between seasons are synchronous in all or at least most sub-regions studied (Table 4.4.1; Figure 4.4.4).

Common guillemots may not be considered a typical example of the Wadden Sea avifauna; other abundant seabirds deserve attention. For most inshore species, as exemplified by shelduck and herring gull, recent oil rates are generally much lower than historic levels within the Wadden Sea. In the Danish part of the Wadden Sea, a recent increase in the oil rates of gulls and other inshore species has been recorded (Durinck and Skov, 2001). Common eider *Somateria mollissima*, shelduck *Tadorna tadorna*, and herring gull *Larus argentatus* were selected as numerous representatives of the Wadden Sea bird population. Because individual winter seasons did not always provide sufficient samples, the data was grouped in time intervals and overall oil-rates were calculated. The most recent period (1999-2003, *i.e.* after the area became designated as a Special Area) may now be compared with results from the 1990s and 1980s (Table 4.4.2). Exceptionally high, starvation-induced natural mortality in the eider over the most recent winters, leading to artificially lowered oil rates, hindered the possibilities for a comparison of results prior to and after 1999. Two trends are apparent: (1) higher oil rates in the 1980s than in recent years, and (2) for each species, higher oil rates along North Sea shores than within the Wadden Sea itself. The first trend is in agreement with overall declines in oil pollution reported in Western Europe, the second is in line with earlier conclusions that the North Sea (and the shipping lanes in it) is much more oil-contaminated than the Wadden Sea area.

4.4.6 Conclusions

The results of beached bird surveys in the Wadden Sea area and its approaches indicate that oil rates have declined significantly over the last decades. The decline is most prominent in the Wadden Sea itself, whereas oil rates of birds found along North Sea shores (including the North Sea side of the Wadden Sea islands) are consistently higher than those in the Wadden Sea. Pelagic seabirds, notably common guillemots, still have relatively high oil rates and the recent designation of North West European waters as a Special Area under MARPOL Annex I (enforced in 1999) has not yet lead to a drastic further decline in oil contamination levels on beached birds. Data from the German North Sea coast suggests further declines after 1999, but recent observations in The Netherlands (winter 2002/03, and winter 2003/04) suggest a re-

Table 4.4.2:
Grouped oil rates in shelduck, common eider and herring gull (% oiled of total number found) in the sub-regions in and around the Wadden Sea since winter 1984/85. Blank cells indicate insufficient data (sample <25 individuals). See Table 4.4.1 for sub-regions.
ns = North Sea exposed (coast of the island facing the North Sea),
ws = Wadden Sea exposed (mainland coast as well as island coast facing the mainland).

	DK	FRG Hel ns	FRG Nds ws+ns	FRG Nds ns	FRG SH ws+ns	FRG SH ns	FRG Nds+SH ws	NL ws	NL islands	NL mainl.
Shelduck										
<1990	17.0	50.9			10.2			4.8	21.9	21.7
1990-1998				2.3	0.0	9.9	8.7	1.3	8.9	3.3
1999-2003				4.3		0.0	1.9	3.9		
Common eider										
<1990	55.1	29.1	16.7		58.2			10.8	51.4	95.5
1990-1998	44.2		15.9	7.5	14.1	23.0	26.4	6.7	3.4	15.4
1999-2003	0.0		3.4	1.4		2.7	1.6	1.2	2.1	14.2
Herring gull										
<1990	31.6	18.0	1.5		12.6			12.2	23.1	20.2
1990-1998	23.6	17.5	6.1	1.6	12.5	16.7	1.2	4.1	21.0	14.4
1999-2003	8.6	0.0		4.0		4.5	1.2	3.4	11.1	25.0

versed trend, with very high oil rates in pelagic seabirds and repeated strandings of oil slicks on beaches (NZG/NSO unpubl. material). This reversal can only partly be attributed to some unfortunate recent oil incidents, such as the sinking of the Tricolor and the Assie Eurolink in December 2002. For most inshore species, as exemplified by shelduck and herring gull, recent oil rates are generally much lower than historic levels within the Wadden Sea).

It is too early yet, to assess effects of the designation of the PSSA Wadden Sea in 2002. Longer data sets are necessary to find correlations to the measures taken on the different levels to reduce oil pollution in the area concerned.

4.4.7 Target evaluation

A specific target regarding beached oiled birds has not been formulated in the Wadden Sea Plan until now. However, the Ecological Quality Objective (EcoQO), as developed within the OSPAR framework and described above, can be applied and evaluated.

Although an overall decline in oil rates since the mid 1980s is obvious, the Ecological Quality Objective (EcoQO) of an oil rate of less than 10% in common guillemots has not yet been reached.

4.4.8 Recommendations

Continuation of beached bird surveys in each of the three countries as an important monitoring tool to evaluate trends in chronic oil pollution at sea is strongly recommended. The analysis presented here suffered from inconsistencies over time in the choice of sub-regions, shortening data series and reducing the statistical power of the material. It is therefore strongly recommended to keep the most recent subdivision of the survey area in the future, so that trends can be followed with greater confidence.

It is of great importance to maintain the spread of observer activity over the entire winter period, and not to fall back to a level of isolated midwinter surveys. The Beached Bird Surveys in the framework of the TMAP should be ensured over the entire winter period with harmonized survey frequency in the three Wadden Sea states.

The implementation of the analysis of oil from bird feathers and beach samples is strongly recommended (*cf.* Dahlmann *et al.*, 1994; Fleet and Reineking, 2001). Uncertainties with regard to the sources of oil pollution, issues that are difficult to deal with in aerial surveys and satellite monitoring programs, can be solved this way. Oil analysis of beach and/or feather samples can also be successfully used as legal evidence in prosecuting oil discharge by ships (Dahlmann, 1991) and for North Sea wide oil pollution control measures.

With North West European waters established as a Special Area under MARPOL Annex I, a lot has been achieved. However, just making an area a Special Area is rather pointless if this is not enforced by (national) law and if this law is not adequately implemented. It is clear that additional measures are required to make sure that mariners obey the regulations and stop discharging oil or oily waters (<15 ppm) within this area. Among others, the following actions regarding pollution prevention as well as control and enforcement measures would help to reduce chronic oiling as a threat to marine wildlife:

- Mandatory on-board transponders and oil fingerprinting of all vessels in North Sea waters would facilitate surveillance, enforcement and the prevention of pollution;
- Harmonization and implementation of the EC Directive 2000/59/EC on port reception facilities, including 100% indirect financing of waste collection;
- Implementation of a ship accreditation system for skippers who promote and adopt best environmental practices and have clean environmental records;
- Increase of co-operation between EU-countries, including information exchange and increased frequency of joint exercises regarding, for example, aerial surveys;
- Stronger legal deterrence. Imposed (minimum) fines must be increased to clearly reflect the full extent of the crimes under both shipping and environmental laws;
- Improvement / extension of aerial surveillance.

As a more specific step to try and reduce oil rates in seabirds (and to protect sensitive areas), it is recommended to identify, monitor and protect sensitive areas at sea in the North Sea, also areas other than the PSSA Wadden Sea. Spatial patterns and seasonal trends in vulnerable concentrations of seabirds in the North Sea and west of Britain have been identified and published. Despite this knowledge, there is little evidence that this information is being used to improve planning of clean-up operations (*e.g.* Tricolor incident), in the decision process to either immediately combat illegal spills at sea or leave them to disperse naturally (and slower), or in the planning of aerial surveillances for oil at sea. A stronger emphasis on the most vulnerable areas could help to reduce the oil problem.

A final step is education. During training of sea cadets it should be emphasized that even a very small amount of discharged oil can cause immediate and serious damage to the environment, and that it is not so much the amount of oil spilled but the time and location where the oil is released that leads to significant mortality among seabirds and other marine wildlife. It may at least be hoped that the information provided will be remembered and that an illegal discharge will be recognized as a criminal act by the offender himself.

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4.5 Contaminants in Bird Eggs

Peter H. Becker
Jacqueline Muñoz Cifuentes

4.5.1 Introduction

Since 1998, the parameter 'Contaminants in Bird Eggs' has been implemented in the Trilateral Monitoring and Assessment Program (TMAP) (Becker *et al.* 2001). Each spring, eggs of the common tern and oystercatcher were sampled from a total of 13 breeding colonies in the Wadden Sea (Figure 4.5.1). In these eggs concentrations of mercury, polychlorinated biphenyls (PCBs) and a number of organochlorines, including pesticides, were determined. This contribution presents and evaluates the latest levels of contaminants in bird eggs from the Wadden Sea and their recent trends as reported in more detail in Becker and Muñoz Cifuentes (2004). We focus on the geographical variation of contamination from The Netherlands to Denmark in 2002, and on temporal trends for three periods, *viz.* 1998–2003, 1991–2003 and 1981–2003. For the first time, temporal trends of chlordane levels, which have been analyzed since 1998, are presented.

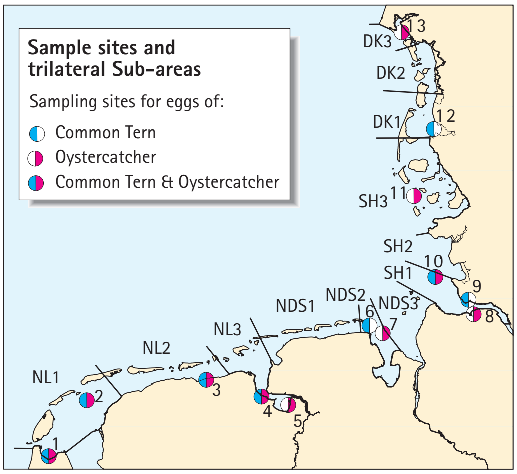


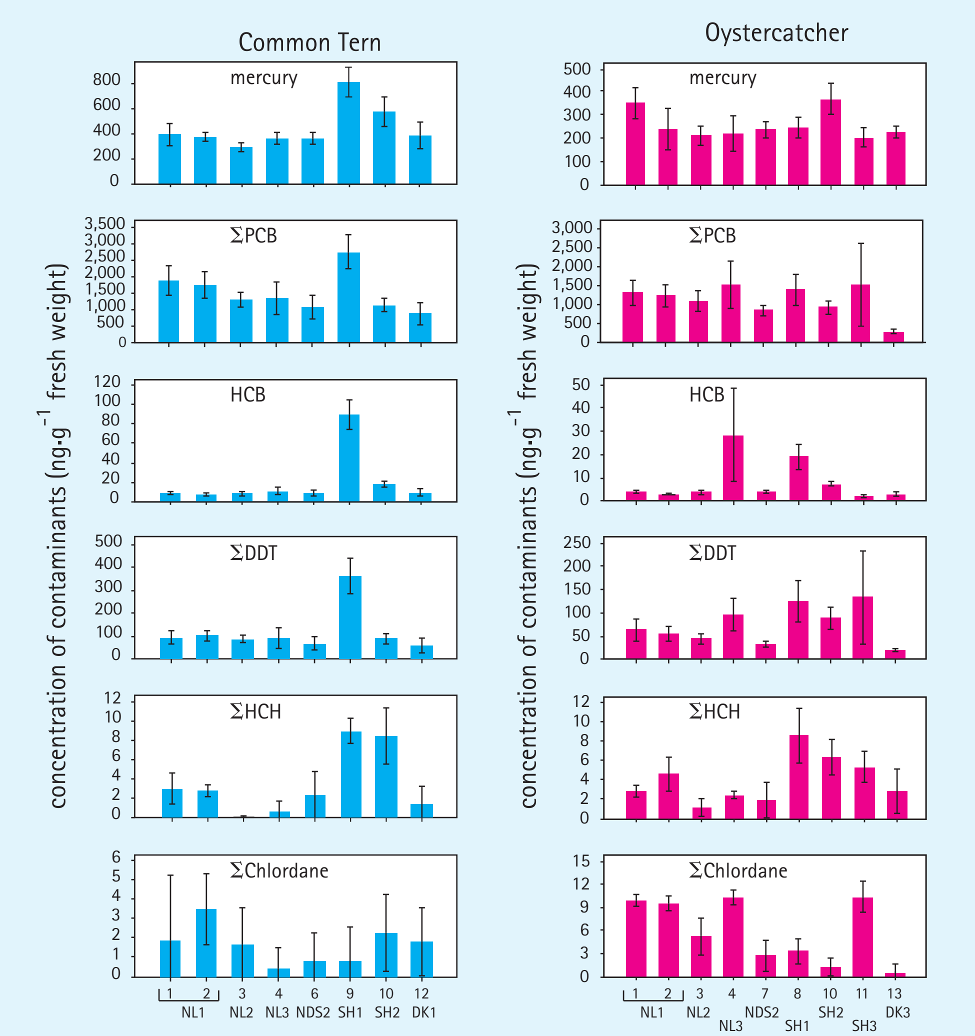
Figure 4.5.1: Sampling sites and geographical variation of the contaminants analyzed in common tern and oystercatcher eggs in the Wadden Sea in 2002. The Netherlands: 1 Balgzand, 2 Griend, 3 Julianapolder, 4 Delfzijl; Germany, Niedersachsen: 5 Dollart, 6 Minsener Oog, 7 Mellum (6 and 7 = Jade), 8 Hullen, 9 Neufelderkoog (8 and 9 = Elbe estuary); Germany, Schleswig Holstein: 10 Trischen, 11 Norderoog; Denmark: 12 Margrethekoog, 13 Langli. At sites 5, 7, 8, 11 and 13 only oystercatcher eggs, at sites 6, 9 and 12 only common tern eggs were taken; at all other sites eggs of both species were collected.

4.5.2 Geographical trends

The results presented in Figure 4.5.2 reveal that in 2002 the central part of the German Wadden Sea, and the Elbe estuary in particular, still are the hot spots for chemical contamination. The lowest residue levels in eggs of common tern and oystercatcher were recorded in the Danish Wadden Sea. Within the Dutch Wadden Sea, the concentrations of most chemicals (mercury, PCBs, DDT, and chlor-

Common tern breeding pair (Photo: Dietrich Frank)

Figure 4.5.2: Geographical variation of the contaminants analyzed in common tern and oystercatcher eggs in the Wadden Sea in 2002. The Netherlands: 1 Balgzand, 2 Griend, 3 Julianapolder, 4 Delfzijl; Germany, Niedersachsen: 5 Dollart, 6 Minsener Oog, 7 Mellum (6 and 7 = Jade), 8 Hullen, 9 Neufelderkoog (8 and 9 = Elbe estuary); Germany, Schleswig Holstein: 10 Trischen, 11 Norderoog; Denmark: 12 Margrethekoog, 13 Langli. At sites 5, 7, 8, 11 and 13 only oystercatcher eggs, at sites 6, 9 and 12 only common tern eggs were taken; at all other sites eggs of both species were collected. Mean concentration (ng·g^{-1} fresh weight of egg content) and 95% confidence intervals are presented. At most sites, n=10 eggs per species were analyzed.



danes) decreased from west to east. For PCBs and chlordanes, this spatial trend continued towards the north-eastern Wadden Sea, indicating pollutants mainly originating from southwest sources (*e.g.* Rhine). In addition, the Ems estuary was recognized as a pathway discharging contaminants into the Wadden Sea, which was reflected by higher levels of HCB and chlordanes in oystercatcher eggs.

4.5.3 Temporal development

An overview of temporal trends as observed in the periods 1991-2003 and 1998-2003 is presented in Figure 4.5.3 and Table 4.5.1. When considering the data from 1981–2003 for the central German Wadden Sea, it is noted that residue levels in eggs of common cern and oystercatcher have decreased markedly since the beginning of the 1990s, especially regarding mercury, ΣPCB, HCB and ΣHCH (Figure 4.5.4). During the 1990s, these levels were roughly less than half of those observed in the previous decade. Since the mid 1990s, however, the decrease of egg concentrations seemed to have stagnated at levels still above the target concentrations. The data from 1998–2003 surprisingly reveals a recent increase of the concentration levels of some of the pollutants (Figure 4.5.3, Table 4.5.1; *e.g.* mercury: Balgzand, Jade, Trischen, Langli; ΣPCB: Dutch Wadden Sea, Jade; ΣDDT: Dutch Wadden Sea, Elbe). Chlordane concentrations in eggs of common tern and oystercatcher seem to show an overall increase at most sampling locations.

Concomitant with the overall decreasing concentration levels of contaminants in bird eggs, the strong inter-site and inter-specific differences as present during the 1980s have also decreased (Figure 4.5.5).

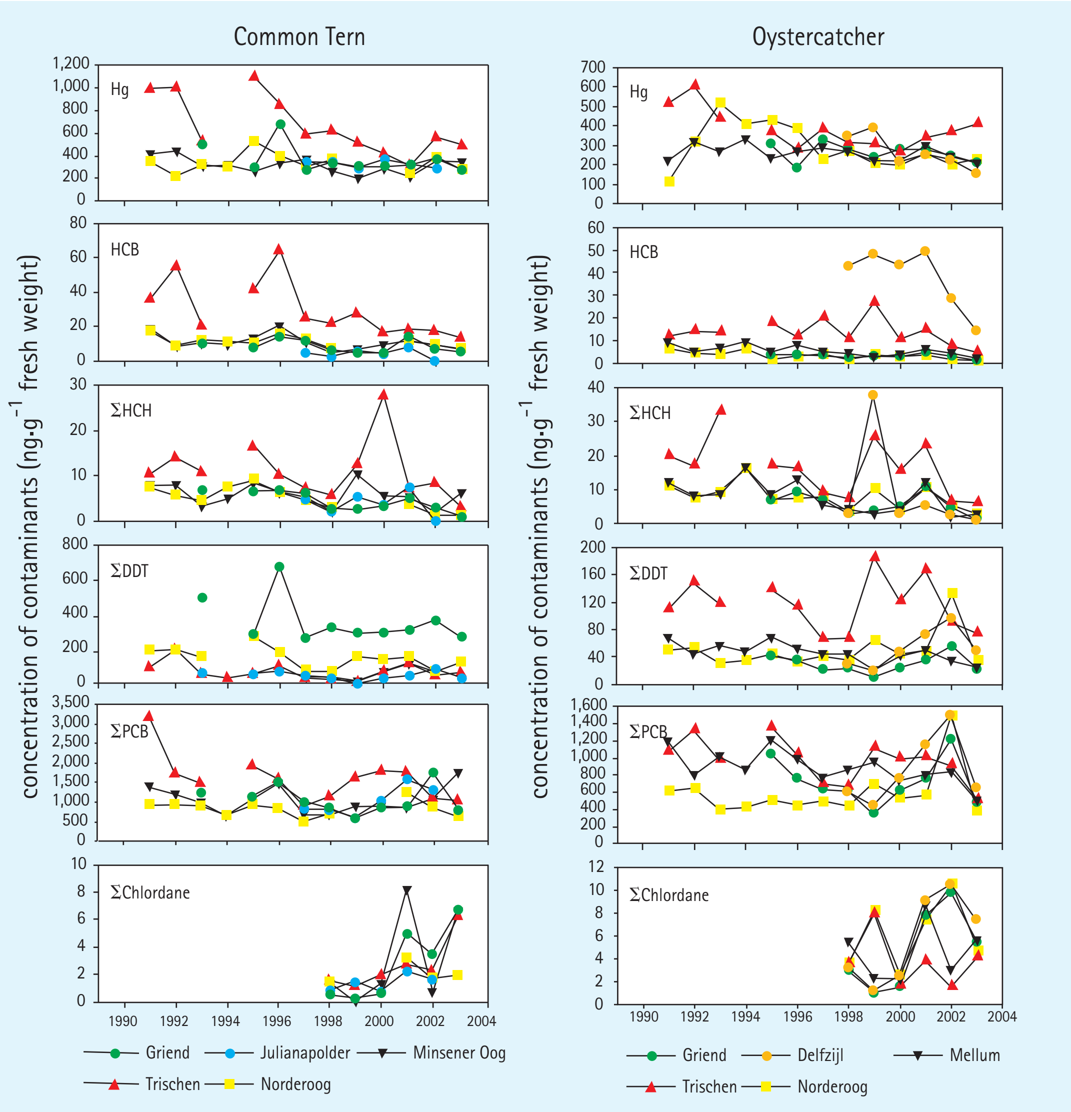


Figure 4.5.3: Temporal trends of mercury, HCB, sum of HCH-isomers (ΣHCH), sum of DDT and its metabolites (ΣDDT), sum of PCB congeners (ΣPCB), and sum of cis- and trans-chlordane, cis- and trans-nonachlor (ΣChlordane) concentrations in eggs of common tern (left) and oystercatcher (right) from selected sampling sites in 1991-2003. Arithmetric means ($ng \cdot g^{-1}$ fresh weight of egg content).

4.5.4 Ecotoxicological aspects

The current levels of contaminants in bird eggs were generally below the known critical concentrations for birds' reproduction. Hatching success of the common tern at relatively high and low contaminated sites at the German Wadden Sea coast did not differ (Thyen *et al.*, 1998; Becker *et al.*, 2003). More recently, Muñoz Cifuentes (2004) presented data from the mid 1990s suggesting that at the Elbe estuary reproductive success of the common tern, common gull and herring gull was affected by organochlorine contamination. Monitoring of birds' breeding success is not included in the TMAP Common Package of monitoring parameters.

4.5.5 Target evaluation

The available data on concentrations of contaminants in bird eggs indicates that the burden of pollutants in the Wadden Sea is slowly proceeding towards the Wadden Sea Plan Targets. On the other hand, the stagnation and, more recently, some increases, point to local problems from recent anthropogenic discharges. Among these are contaminants prohibited a long time ago, such as chlordanes.

The present concentrations of PCBs and DDT, especially in the eggs of common tern, are still very high in comparison with the proposed target levels, whereas for HCB and HCH the target may be reached fairly soon. In the case of mercury, the recent concentrations measured in eggs of oystercatcher and common tern, e.g. at the Elbe estuary, are still higher than target concentrations.

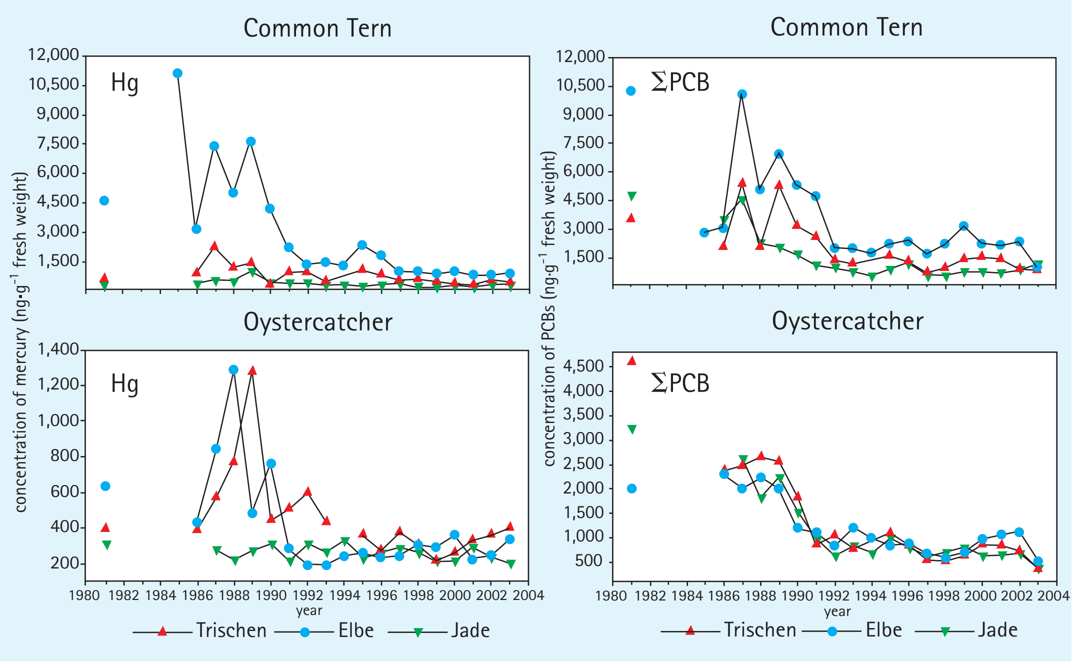


Figure 4.5.4: Temporal trends of concentrations of mercury (left) and PCB (right) (ΣPCB: sum of 32 PCB congeners; $ng \cdot g^{-1}$ fresh weight; arithmetic means) in eggs of common tern and oystercatcher from selected breeding sites in the central German Wadden Sea in 1981–2003. Data for 1981–1990 after Becker *et al.* (1991, 1992).

4.5.6 Conclusions

The monitoring of mercury and organochlorines in bird eggs in the TMAP has significantly contributed to the understanding of the dynamics and trends in levels of these hazardous chemicals in coastal birds in the Wadden Sea environment.

In 2002, the central part of the German Wadden Sea, and the Elbe estuary in particular, was still a hot spot for chemical contamination and supplementary inputs in the western part of the Wadden Sea were obvious.

Since the beginning of the 1990s, concentration levels of most contaminants decreased, leveling off in the mid-1990s. However, since 1998, the concentration levels of some chemicals have increased again, which may indicate new inputs or remobilization of these chemicals from sedimentary deposits.

Recent observations of coastal birds' reproductive success in the Elbe estuary underline the necessity of a continued effort to reduce anthropogenic inputs of hazardous chemicals into the Wadden Sea in order to avoid impacts on bird populations and the ecosystem.

4.5.7 Recommendations

Considering the current contamination status of bird eggs on the Wadden Sea coast and its recent development, we recommend:

- to continue the monitoring of the TMAP parameter 'Contaminants in Bird Eggs' in a long-term perspective, especially at the identified hot spots, in order to separate short term fluctuations from long-term trends and to use the parameter as an early warning of marine pollution by chemicals;
- to continue the monitoring of chemicals, such as chlordane and PCBs, which still remain in the environment although their use is prohibited by law;
- to supplement the geographical coverage of contaminant monitoring in bird eggs with an additional sampling site at the mouth of the Rhine; and
- to implement within the TMAP the parameter 'Breeding Success' providing a sensitive ecotoxicological indicator.

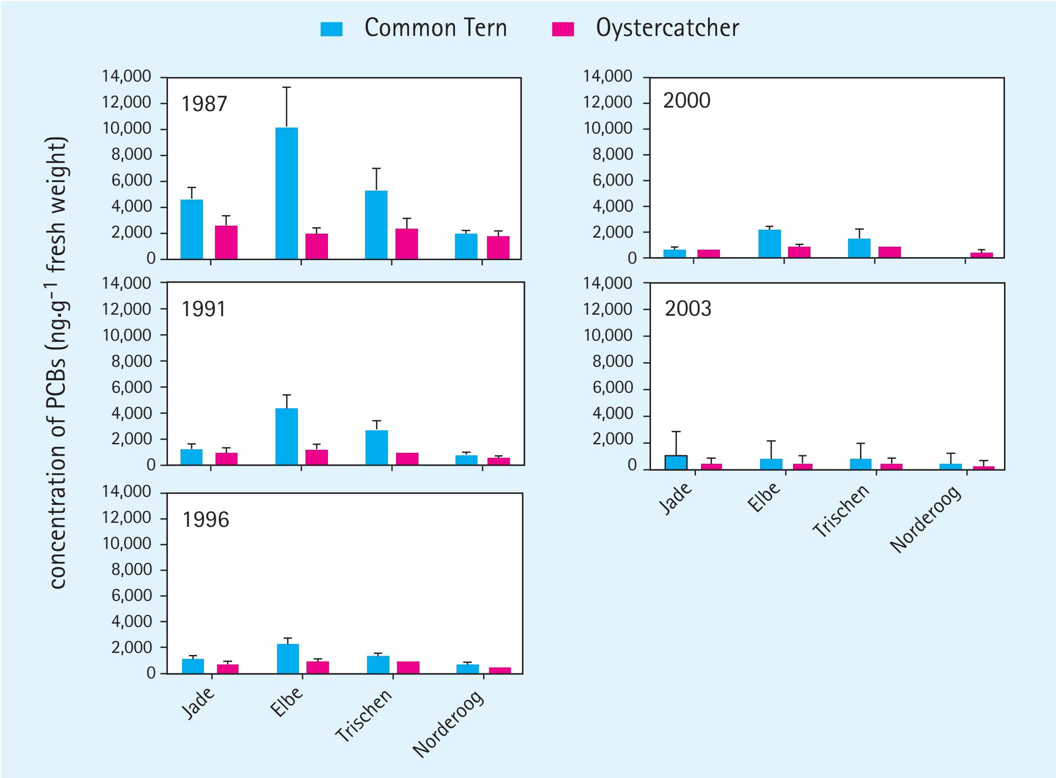


Figure 4.5.5: Temporal, spatial and interspecific variation in ΣPCB concentrations (sum of 32 congeners) in eggs of common tern and oystercatcher from selected breeding sites on the German Wadden Sea coast between 1987 and 2003. Mean concentration ($ng \cdot g^{-1}$ fresh weight of egg content) and 95% confidence intervals are presented.

Table 4.5.1:
Temporal trends in pollutant levels in Common Tern and Oystercatcher eggs for one or two time periods. Chlordanes studied since 1998. For significant trends, Spearman rank coefficients (rs) calculated on the basis of n eggs and p-values are presented. N.s.: not significant, *<0.05, **<0.01*<0.001. Positive trends are given in bold.**

		Hg	n	HCB	n	ΣPCB	n	ΣDDT	n	ΣHCH	n	ΣChlordane	n
Common Tern													
Balgzand	1998-2003	n.s.	60	n.s.	60	n.s.	60	**0,278***	60	-0,528***	60	**0,438*****	60
Griend	1993-2003	-0,320**	100	-0,363***	100	n.s.	100	n.s.	100	-0,698***	100		
	1998-2003	n.s.	60	n.s.	60	**0,282***	60	**0,419****	60	n.s.	60	**0,726*****	60
Julianapolder	1998-2002	n.s.	33	n.s.	33	**0,771*****	33	**0,647*****	33	-0,653***	33	n.s.	33
Delfzijl	1998-2003	n.s.	60	-0,258*	60	n.s.	60	n.s.	60	-0,506***	60	**0,318***	60
Minsener Oog	1991-2003	-0,251**	130	-0,334***	129	n.s.	130	-0,195*	130	-0,274**	130		
(Jade)	1998-2003	**0,418****	60	**0,291***	60	**0,476*****	60	**0,418****	60	n.s.	60	**0,418****	60
Elbe	1991-2003	-0,626***	135	-0,228**	135	-0,269**	135	n.s.	135	-0,250**	135		
	1998-2003	n.s.	60	-0,653***	60	-0,422**	60	n.s.	60	-0,601***	60	n.s.	60
Trischen	1991-2003	-0,548***	120	-0,448***	120	-0,387***	120	-0,352***	120	-0,355***	120		
	1998-2003	n.s.	60	-0,270*	60	n.s.	60	n.s.	60	-0,352**	60	**0,382****	60
Norderoog	1991-2003	n.s.	109	-0,352***	110	-0,205*	110	-0,341***	110	-0,588***	110		
	1998-2003	n.s.	40	n.s.	40	-0,320*	40	n.s.	40	-0,478**	40	n.s.	40
Oystercatcher													
Balgzand	1998-2003	**0,396****	60	-0,283*	60	n.s.	60	n.s.	60	-0,536***	60	**0,654*****	60
Griend	1994-2003	-0,278*	82	-0,315**	82	n.s.	82	n.s.	82	-0,389***	82		
	1998-2003	n.s.	60	n.s.	60	**0,263***	60	**0,408****	60	n.s.	60	**0,620*****	60
Julianapolder	1998-2003	-0,337*	58	-,448***	58	**0,443*****	58	**0,533**	58	-0,647***	58	**0,634*****	58
Delfzijl	1998-2003	-0,579***	60	-0,261*	60	**0,460*****	60	**0,626*****	60	-0,542***	60	**0,682*****	60
Dollart	1991-2003	n.s.	85	-0,322**	75	**0,320****	75	n.s.	75	n.s.	75		
	1998-2003	-0,330*	36	**0,600*****	36	**0,677*****	36	**0,716*****	36	**0,368***	36	**0,414***	36
Mellum (Jade)	1991-2003	-0,276**	130	-0,562***	130	-0,359***	130	-0,494***	130	-0,625***	130		
	1998-2003	n.s.	60	n.s.	60	-0,381**	60	n.s.	60	-0,285*	60	n.s.	60
Elbe	1991-2003	**0,334*****	130	-0,424***	130	-0,218*	129	n.s.	130	-0,289**	130		
	1998-2003	n.s.	60	-0,286*	60	n.s.	60	**0,403****	60	n.s.	60	**0,510*****	60
Trischen	1991-2003	-0,373***	118	-0,346***	118	-0,406***	118	n.s.	118	-0,503***	118		
	1998-2003	**0,423****	58	-0,627***	58	n.s.	58	n.s.	58	-0,336*	58	n.s.	58
Norderoog	1991-2003	-0,276**	129	-0,512***	129	n.s.	129	n.s.	129	-0,490***	129		
	1998-2003	n.s.	59	-0,389**	59	n.s.	59	n.s.	59	n.s.	59	**0,268***	59
Langli	1999-2002	**0,453****	40	n.s.	40	n.s.	40	n.s.	40	-0,579***	40	n.s.	40

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4.6 Newly Emerging Xenobiotics

Joop F. Bakker
Martine van den Heuvel-Greve
Dick Vethaak

New compounds are being developed continuously. Life Cycle Analysis (LCA) is an important feature in this development, but still no guarantee for environmental safety. In the marine environment, compounds are still being found that should have been eliminated in waste water treatment plants. Diffuse application is an uncontrollable source of many compounds. The need for ever more effective compounds and their great economic importance still results in powerful pollutants ending up in the environment. In this section, some compounds/groups of high political priority are described for the first time in a QSR Wadden Sea.

4.6.1 Brominated Flame Retardants (BFRs)

BFRs are widely produced and used throughout the world to reduce the flammability of materials, mostly synthetic polymers. Flame retardants (FRs) slow down the initial burn rate, thereby increasing the time span to 'flash-over', the moment that the generated heat sets all combustible materials on fire instantly.

The compound group belongs to the (halogenated) flame retardants ((H)FRs) and can be split into four different types (BSEF, 2000):

- Tetrabromobisphenol-A (TBBPA)
- Hexabromocyclododecane (HBCD)
- Polybrominated Biphenyls (PBBs)
- Polybrominated Diphenyl Ethers (PBDEs)

As BFRs are considered to be the most cost and performance effective, they constitute 25-39% of the global application of flame retardants, and are mainly used in construction materials (*e.g.* foams), electronics (*e.g.* circuit boards, plastic housing) and electrical isolation materials. Other groups of FRs are also in use, where the choice depends on the type of application. On the world market (1998) BFRs have a share of 39% (BSEF, 2000).

DeCarlo (1979) was the first to report on BFRs in environmental samples, but only recently have BFRs been recognized as an environmental problem by policy in the Water Framework Directive. Nearly 20 years later, BFRs were found in sperm whales (*Physeter physeter*) (de Boer *et al.*, 1998). Here, a parallel to the story of PCBs is apparent. Due to their high lipophily and bioconcentration the compounds HBCD, TetraBDE (BDE 52-81), PentaBDE (BDE 82-104) and HexaBDE (BDE 128-169) are considered to pose an environmental problem. Both lipophility and bioconcentration are determined by the bromination level, where molecular weights greater than 700 are highly lipophilic but have no tendency to bioconcentrate in fish (Hardy, 2004). Deca-BDE (BDE 209) is supposed to be one of these non-bioconcentrating BFRs, due to either a low uptake rate (Hardy, 2004; BSEF, 2000), or a rapid metabolism (Boon *et al.*, 2002). Recently, however, WWF (2004) showed by far the highest BFR levels in human blood serum for Deca-BDE. Since cases of bioaccumulation were all found in lung-breathers, the uptake of this group of compounds may be faster than the metabolism and/or excretion.

4.6.1.1 Inputs

Few data are available on riverine, atmospheric or point source inputs of BFRs. In a recent study at near-Wadden Sea locations, BFRs in wet precipitation were below detection limits (Peters, 2003).

In Europe two BFR manufacturing plants are located near the borders of the North Sea, *viz.* GLCC (Aycliffe, UK) and Dead Sea Bromine (Terneuzen, NL), and thus through sea currents connecting to the Wadden Sea. At the latter location high concentrations of HBCD were found in wet precipitation (Peters, 2003).

4.6.1.2 Concentrations in sediment

Historical data about BFRs in sediment of the Dutch Wadden Sea is shown in Figure 4.6.1. Deca-BDE (BDE 209) was by far the dominant BFR (emerging between 1965 and 1978) at a 10 to 20 times higher concentration than Tri-BDE (BDE-28), Tetra-BDE (BDE-47) and Penta-BDE (BDE 99).

Sediment concentrations in the Dutch North Sea coastal zone and Wadden Sea were reported by Åkerman *et al.* (2004) and Klamer *et al.* (2002). In both reports BFRs show highest maxima of BDE209 and HBCD in the Wadden Sea and off Terschelling both in sediments and suspended matter (Figure 4.6.2). Only the Western Scheldt at Hansweert (close to the Dutch-Belgian border) had

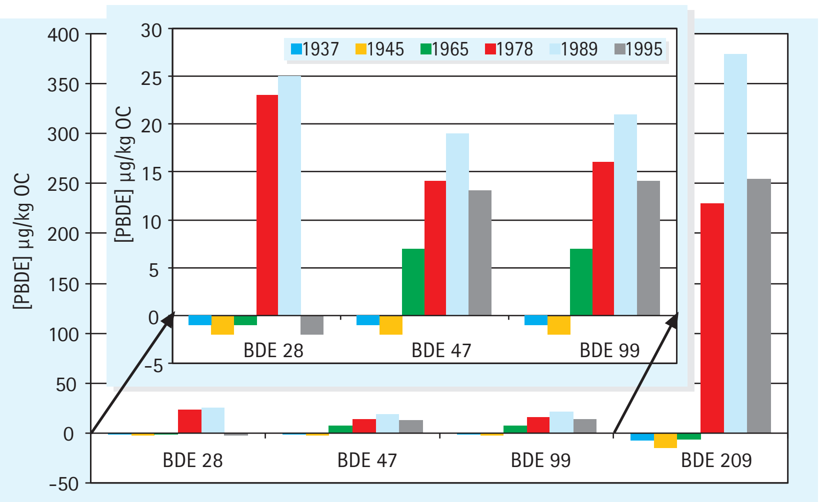

Figure 4.6.1: PBDE concentrations (µg kg^{-1} organic carbon) in dated layers of a sediment core acquired at the western Dutch Wadden Sea. The insert shows the values of BDE 28, 47 and 99 at an enlarged scale. Concentrations below the detection limit are shown as negative values (source: Zegers *et al.*, 2003).

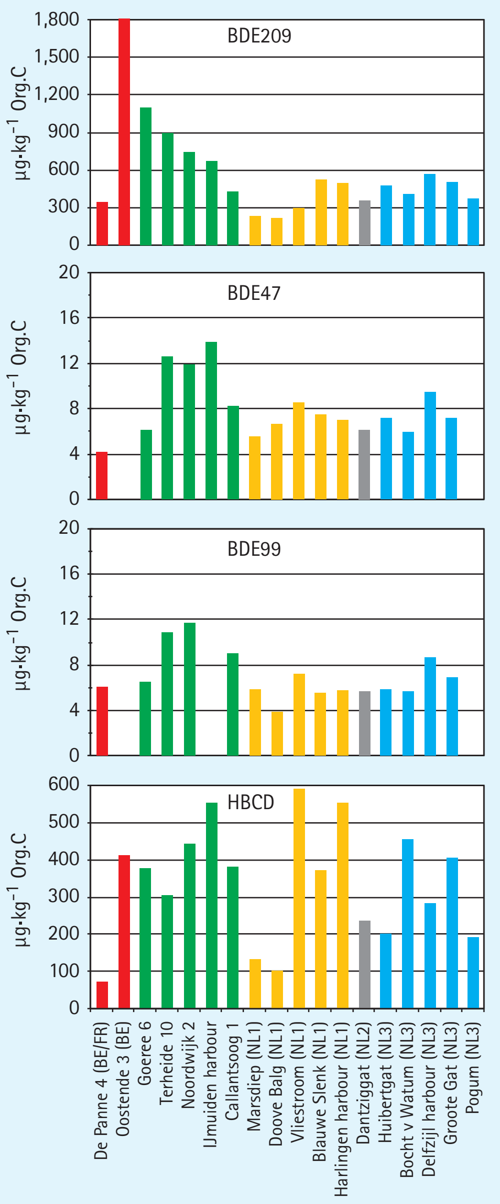

Figure 4.6.2: Contents (µg·kg^{-1} organic carbon) of poly-bromo-diphenylethers (PBDEs 209, 47, 99) and hexa-bromo-cyclododecane (HBCD) in suspended matter and along the Dutch and Belgian coast (BE), in the Dutch Wadden Sea and Ems estuary in 2003. Number following location name indicates the distance off the coast (km), (source: Åkerman *et al.*, 2004).

higher levels (data not shown). In 2003, BDE209 levels ranged from 25 µg kg^{-1} in suspended matter to 200 µg kg^{-1} in sediments. HBCD levels ranged from 30 µg kg^{-1} in suspended matter to 45 µg kg^{-1} in sediments (all levels normalized at 5% organic carbon).

4.6.2 PerFluorinated Octane Sulfonates (PFOS)

Perfluoroctane sulfonate (PFOS) and perfluoroctanoic acid (PFOA) belong to the group of perfluorinated chemicals (PFCs), in which fluorine is strongly bonded to variable lengths of carbon chains (*e.g.* Teflon). PFOS and PFOA are synthetically produced or (PFOA) the break-down product of PFCs. The heat stable, persistent and both hydro- and lipophobic properties of these compounds have found extensive application in repellents and coatings. The largest producer in the USA (3M) announced to phase out PFOS and PFOA in May 2000, due to revealed wide distribution of these compounds in wild life and humans (WWF, 2004).

4.6.2.1 Concentration in sediment and biota

In 2003, PFOS and PFOA were found in sediments of all Dutch freshwater and estuarine/marine locations investigated (Schrap *et al.*, 2004; Åkerman *et al.*, 2004). In Wadden Sea sediments PFOA was below the limit of detection of the not yet fully validated analytical procedure. PFOS contents ranged from 1.5-0.4 µg kg^{-1} (at 5% organic carbon).

In 2003, first data on presence of PFOS and PFOA in blue mussels (*Mytilus edulis*) and flounder (*Platichthys flesus*) were all below the limit of detection (Schrap *et al.*, 2004). These compounds do however occur in humans. In the Detox campaign of the World Wildlife Fund, PFOS and PFOA were analyzed in human whole blood (WWF, 2004). Seven to eight perfluorinated acids were found, in which PFOA and PFOS were predominant.

4.6.3 IRGAROL

The compound N'-tert-butyl-N-cyclopropyl-6-(methylthio)-1,3,5-triazine-2,4-diamine (IRGAROL 1051) is used as the active ingredient of anti-fouling agents and paints. Its application is world wide and the compound is found in coastal and estuarine waters and sediments. Few measurements on IRGAROL are available. IRGAROL is not recognized as a 'chemical of priority action' (OSPAR, 2002) nor subject to 'ecotoxicological assessment criteria' (OSPAR, 2003).

4.6.3.1 Input

Anti-fouling paints containing IRGAROL were introduced on the European market around 1985, being solely produced by Ciba Specialty Chemicals Inc. (Rasenberg and van de Plassche, 2002). Main sources of environmental contamination are located at maintenance sites (shipyards) and harbors (leaching). IRGAROL leaches out of the paints at about 2.6-5 ng·cm^{-2}·day^{-1}. In comparison, TBT leaches at a rate of 4,000-5,000 ng·cm^{-2}·day^{-1} (Rasenberg and van de Plassche, 2002).

4.6.3.2 Concentrations in water, sediment and biota

In the few measurements available, IRGAROL ranges from 28 (in marinas) to 0.2 (open Dutch Wadden Sea) ng·l^{-1} in water and was not demonstrat-

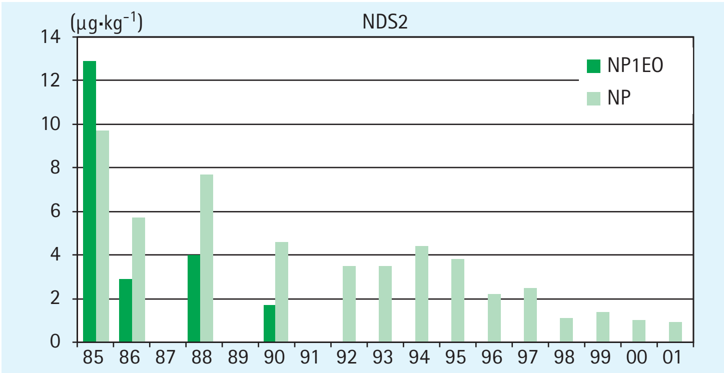

Figure 4.6.3: Contents of nonylphenol (NP) and nonylphenol monoethoxylate (NP1EO) (µg kg^{-1} wet weight) in blue mussels in the Jade Bight (NDS2) (source: Environmental Specimen Bank, Wenzel *et al.*, 2004).

ed in sediments (Bellert and van de Ven, 2003). Ecotoxicological effects are not expected at concentrations of up to 0.24 ng·l^{-1} (van Wezel and van Vlaardingen, 2001), implying that IRGAROL exceeded this upper limit by a factor of more than 100. Although IRGAROL is considered as hardly biodegradable, bioaccumulation does not occur due its quick elimination and low Log K_{ow}.

4.6.3.3 Ecotoxicological risks

IRGAROL acts on the photosynthetic capacity by blocking the photosystem II (Holt, 1993), implying main toxicological risk to algae, macrophytes and photosynthetic bacteria. Scarlett *et al.* (1997) reports 50% effect levels (EC50) on photosynthetic activity of the green alga *Enteromorpha intestinalis* at 2.5 µg·l^{-1}. Chronic toxicity on growth of the diatom *Skeletonema costatum* was reported at concentrations higher than 0.14 µg·l^{-1} (Jongbloed and Luttik, 1996).

4.6.4 Alkylphenols

Alkylphenols (APs, *a.o.* octylphenol, nonylphenol) and their ethoxylates (APEs, *e.g.* Triton X-100) are used as additives in plastics and as the active ingredient in industrial non-ionic detergents and emulsifiers. Octyl- and nonylphenol isomers are most commonly used (>90%), being the world's second largest class of non-ionic surfactants (Metcalfe *et al.*, 1996). Environmental sources are cleansing applications (textile, tapestry, bulk tanks) and agricultural pesticide emulsions (Maguire, 1999). APs are moderately water soluble, while APEs are more soluble.

Alkylphenols are of environmental concern due to their hormonal disruptive action (xeno-estrogens). Maguire (1999) concluded that initial breakdown of parent NPEs occurs readily in sewage treatment plants, resulting, however, in metabolites more persistent in the environment and toxic to aquatic organisms. Nonylphenol is such a breakdown product, showing acute or chronic toxicity at about 20 or 4 µg·l^{-1} respectively, in fish, invertebrates and algae (Servos, 1999). Municipal effluents in The Netherlands in 1999 had alkylphenol concentrations up to 1.5 µg·l^{-1}, compared to up to 39 µg·l^{-1} in untreated industrial waste. The effluent solids, however, contained up to 70 mg·kg^{-1} dry weight nonylphenolethoxylate and 3.4-12 mg·kg^{-1} dry weight nonylphenol (Vethaak *et al.*, 2002). The number of ethoxylate units and water solubility of APEs is inversely related. Nonylphenol is poorly soluble in water and tends to adsorb to sediment and bioaccumulate, as shown by its octanol-water partition coefficient (Log K_{ow}) of 4.3 (Maguire, 1999). This explains the observations in the municipal effluents.

4.6.4.1 Input

APs and APEOs in wet precipitation mainly consisted of nonylphenolethoxylate (NPE) and its parent nonylphenol (Peters, 2003). Around the Dutch Wadden Sea, the concentrations were at minimum, ranging 0.03-0.04 µg·l^{-1}.

Major input of alkylphenols into the environment originates from agricultural applications where there is no possibility for sewage treatment. In The Netherlands, agriculture is responsible for 77% of the NPE input into the environment, whereas it uses only 35% of the total NPE consumption (Groshart *et al.*, 2001b).

4.6.4.2 Concentrations in sediment and biota

In the Dutch Wadden Sea and Ems estuary, concentrations of NP and NPE in sediment and suspended matter were 34 and 33 mg·kg^{-1} DW, respectively. NPE concentrations in flounder (*Platichthys flesus*) were low (0.1 mg·kg^{-1} wet weight) and below the detection limit in blue mussels (*Mytilus edulis*) (Vethaak *et al.*, 2002).

In the German Wadden Sea (NDS2), the concentrations of NP and NPE in blue mussels (*Mytilus edulis*) have decreased strongly since the 1980s after the production was stopped completely in Germany (Figure 4.6.3) (Wenzel *et al.*, 2004).

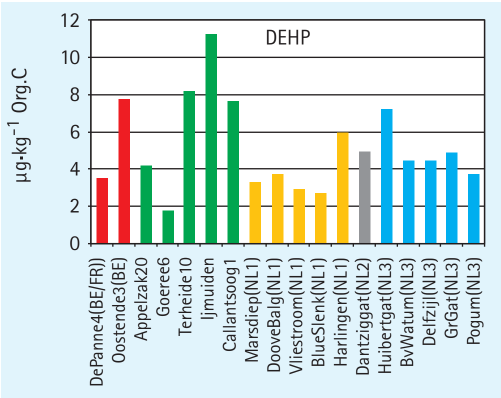

Figure 4.6.4: Content of di(2-ethylhexyl)phthalate (DEHP; mg kg^{-1} organic carbon) in suspended matter of the Belgian-Dutch North Sea coast, in the Dutch Wadden Sea and Ems estuary in 2003. DEHP-free sampling equipment was used. (source: Åkerman *et al.*, 2004).

4.6.5 Bisphenol-A

Bisphenol-A (BPA) is an important intermediate in the production of epoxy resins, polycarbonate and flame retardants. The global production of BPA increased from 1.1 million ton in 1993 to an estimated 2,6 million ton in 2002. Its chemical properties make BPA relatively hydrophilic (Groshart *et al.*, 2001a).

BPA is toxic to fish and invertebrates (at 1-10·10^{3} µg·l^{-1}) and readily degradable (Staples *et al.*, 1998). Toppari *et al.* (1995) report estrogenic potential, which is why BPA is included in the list of suspect endocrine disruptors (see section 4.7.1).

4.6.5.1 Input

Major emission sources to surface waters estimated by Groshart *et al.* (2001a) are thermal paper recycling (~72 %) and production of plastics (PVC, Phenoplast, ~21 %).

4.6.5.2 Concentrations in water, sediment and biota

Vethaak *et al.* (2002) report high concentrations of BPA (100-320 ng·l^{-1}) in surface water of the Dutch Wadden Sea and Ems-Dollard estuary in 1999. These high concentrations may be related to the industrialized area of Delfzijl, and compare to levels in polder ditches and rivers Rhine and Meuse. In comparison, concentrations found in other Dutch coastal waters range from below detection limit (North Sea) to 80 ng·l^{-1} (Western Scheldt) (Vethaak *et al.*, 2002).

BPA was not found in sediment of the Dutch locations investigated (Vethaak *et al.*, 2002), but BPA did occur in Wadden Sea flounder (*Platichthys flesus*) muscle tissue (1.2-2.6 µg·kg^{-1} wet weight [24% dry weight]) and blue mussel (*Mytilus edulis*) tissue (18-22 µg·kg^{-1} wet weight [~20% dry weight]) (Vethaak *et al.*, 2002).

4.6.6 Phthalates

Phthalates are a large group of 'softeners' widely used in many plastics. In some plastics, such as flexible PVC, phthalates constitute 50% of the total weight. Alternative applications are phthalate additions to heat-exchange fluids, ink, paint, adhesives, pesticides (Vethaak *et al.*, 2002). About 2.7·10^{9} kg·y^{-1} of phthalates are produced globally (van Wezel *et al.*, 1999), the major part of which is used in PVC (WWF, 2004).

In the marine environment Di (2-ethylhexyl) phthalate (DEHP) is predominant. Due to its high hydrophobicity (K_{ow} = 7.5; Staples *et al.*, 1997) DEHP adsorbs to sediments and suspended matter (Furtmann, 1999) and bioaccumulates. Due to their bi-polar structure phthalates may form micelles in water, increasing their apparent solubility (Staples *et al.*, 1997).

Biodegradation of phthalates occurs, with a reported half-life of 20-40 days for DEHP. DEHP, however, is found in North Sea sediments in high concentrations (Åkerman *et al.*, 2004).

Due to the wide spread use of phthalates, specifically of DEHP, in plastics, uncontaminated sampling is a tedious job.

4.6.6.1 Input

Vethaak *et al.* (2002) report high levels of DEP and DEHP in Dutch sewage sludge of up to 15 mg·kg^{-1} dry weight to 50 mg·kg^{-1} dry weight respectively. Most input is from diffuse sources and thus not well documented.

4.6.6.2 Concentrations in sediment, suspended matter and biota

In fluvial sediments and suspended matter, concentrations of DEHP were found to be up to 50 times higher than in marine sediment and suspended matter (Vethaak *et al.*, 2002).

In Figure 4.6.4 the latest data about DEHP in suspended matter of the Dutch Wadden Sea is shown, obtained from samples collected with a specially prepared centrifuge in order to minimize DEHP contamination (Åkerman *et al.*, 2004). Concentrations in suspended matter of the Wadden Sea locations ranged 150 – 350 µg kg^{-1} at 5% organic carbon (3-7 mg kg^{-1} org. C).

Vethaak *et al.* (2002) only report Di-ethylphthalate (DEP) concentrations in flounder (*Platichthys flesus*) of 10 µg·kg^{-1} wet weight for the western Dutch Wadden Sea. In comparison, DEHP was the predominant phthalate present in the blood of 45 out 47 members of the European Parliament, ranging from 37 to 1200 (median: 160) µg·kg^{-1} whole blood (WWF, 2004).

4.6.7 Polycyclic musk fragrances

Polycyclic musk compounds such as Galaxolide (HHCB) and Tonalide (AHTN) are used as substitutes for the more expensive original musk in personal care products. In contrast to the original fragrance, synthetic musks are persistent in the environment and accumulate in aquatic organisms. Synthetic musk compounds are only slightly toxic but are long-term inhibitors of the cellular defense system (multixenobiotic resistance), which may aggravate adverse effects of other pollutants.

In Figure 4.6.5, HHCB and AHTN concentrations are shown for blue mussels since adverse effects of these substances on the cellular defense system have been demonstrated in this species. Perfume and consumer product companies began to phase out their use of polycyclic musks in Europe in the mid of 1990s, and a slow decrease in the concentrations in marine organisms can be observed (Wenzel *et al.*, 2003).

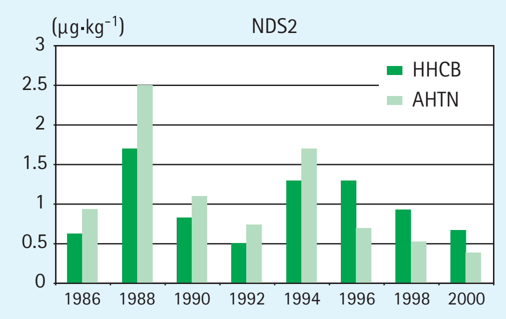

Figure 4.6.5: Contents of polycyclic musk compounds Galaxolide (HHCB) and Tonalide (AHTN) (µg kg^{-1} wet weight) in blue mussels in the Jade Bight (NDS2) (source: Environmental Specimen Bank, Wenzel *et al.*, 2003).

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4.7 New Developments

Joop F. Bakker
Martine van den Heuvel-Greve
Dick Vethaak

4.7.1 Xeno-hormonal disruption

OSPAR addresses substances with known or suspected potential endocrine disrupting effects under its Hazardous Substances Strategy, but has not (yet) addressed endocrine disruption as a selection criterion. OSPAR will await the outcome of appropriate test methodologies for endocrine disrupting effects in other international forums such as the OECD and the EC before deciding what criteria could be applied for such effects in the application of the DYNAMEC mechanism (OSPAR, 2003).

4.7.1.1 Reference to the 1999 QSR

In the 1999 QSR only limited attention was given to endocrine disruptors, *i.e.* substances that have a disrupting effect on hormonal processes in organisms including man. PCBs and Tributyltin (TBT) are examples of earlier endocrine disruptors, held responsible for reproductive failures in harbour seals (PCBs) and abnormal development of reproductive organs in marine snails (TBT). Since the 1990s, harmful effects of endocrine disrupting compounds in the aquatic environment have attracted the attention of scientists and water quality managers around the world. The Scientific Committee for Toxicity, Ecotoxicity and the Environment of the European Union reported on the impact of hormone disrupting substances in various species (SCTEE, 1999). The European Commission (CEC, 1999) announced a plan for follow-up actions including a list of potentially hormone disrupting compounds and the development of an international monitoring program. In 2000, the European Parliament accepted a resolution demanding that the precautionary principle be applied to hormone disrupting compounds.

4.7.1.2 Endocrine disrupting compounds

In The Netherlands, some 30 compounds were listed as most suspect of causing hormone disruption and relevant for the Dutch aquatic environment (Gezondheidsraad, 1999). A base-line study was conducted on the occurrence of natural and synthetic estrogens in the aquatic environment (Vethaak *et al.*, 2002, 2005). Table 4.7.1 gives an overview of the compounds measured by this study in the Wadden Sea area. The study showed that almost all selected (xeno-)estrogens were found in municipal and/or industrial waste water. With the exception of three of the hormones, all of these compounds were detected in the aquatic environment. In general, no specific spatial pattern could be detected, except for high concentrations of polybrominated diphenyl ethers (especially BDE 209) in the Western Scheldt estuary (SW Netherlands). Bisphenol-A, alkylphenol ethoxylates and phthalates in particular were present both in fresh and marine waters, indicating diffuse contamination.

Levels of most (xeno-)estrogens in the Dutch aquatic environment were comparable to those reported for, for example, Germany and Denmark. Only phthalates in biota from the Wadden Sea were found in higher concentrations than in other countries. Also high concentrations of Bisphenol-A (up to 330 ng/l) were measured occasionally in the Dutch Wadden Sea. In this case, however, on the basis of the available ecotoxicological data and the measured concentrations, it can be concluded that Bisphenol-A alone does not seem to pose a threat to fish in the Dutch Wadden Sea (Belfroid *et al.*, 2002). On the other hand, recent experimental studies indicate that Bisphenol-A provokes negative effects in snails (Gastropoda) at far lower water concentrations than in fish (Oehlmann *et al.*, 2000).

Offshore oil/gas drilling platforms were identified as a possible source of the alkylphenols NPE and NP (Vethaak *et al.*, 2002, 2005). The high concentrations of these substances at such offshore locations have recently been confirmed by Jonker *et al.* (2004). It is not clear whether the actual source is drilling and production activities or shipping in the same area.

Newly emerging compounds suspect of endocrine disruption include polybrominated flame

Category	Chemical group	Specific chemical
Estrogens	Natural estrogenic hormones	17α-estradiol, 17β-estradiol, estrone
Xeno-estrogens	Synthetic estrogenic hormones Alkylphenol (ethoxylates)	17α-ethynyloestradiol Nonylphenols Nonylphenol ethoxylates Octylphenols Octylphenol ethoxylates
	Bisphenol-A	
	Phthalates	DMP, DEP, DBP, DPP, BBP, DMPP, DCHP, DEHP, DOP
Thyroid-hormone disrupting compound	Brominated flame retardants	Polybromobiphenyls (PBBs) Polybromodiphenyl ethers (PBDEs)

Table 4.7.1: Overview of estrogens and xeno-estrogens measured in the LOES-study in The Netherlands (from: Vethaak *et al.*, 2002).

retardants, such as polybrominated diphenylethers (*e.g.* penta 2,2',4,4',5 BDE99), tri-Bromo-bisphenol A and hexabromo-cyclododecane, artificial musks and possibly perfluorinated surfactants (*e.g.* perfluoro-octylsulphonate, PFOS).

4.7.1.3 Estrogenic Biomarkers

Estrogenic effects in surface waters were estimated by measuring the concentrations of the yolk protein vitellogenin (VTG) in blood plasma of male fish. VTG concentrations in flounder from the Wadden Sea and Ems estuary were mostly low. None of the flounder had the intersex condition 'ovotestis', where female oocytes are found in male testis tissue. This contrasts to the VTG concentrations and ovotestis found in flounder in the estuaries of the polluted rivers Mersey and Tyne in Great Britain (see Vethaak *et al.*, 2005).

So far, there is little indication for estrogenic effects in fish in the Wadden Sea, which may be the result of the limited number of field studies on hormonal disruption in fish and invertebrates in these waters. In the UK and the southern Baltic Sea, such studies have provided clear evidence of endocrine disruption in a variety of fish species such as eelpout and sand goby (Allen *et al.*, 2002; Gercken and Sordyl, 2002).

4.7.1.4 Foodweb transport

Estrogenic activity in the estuarine and marine environment is strongly adsorbed on sediment particles (Allen *et al.*, 2002). Flounder and other species feeding on benthic invertebrates may obtain estrogenic exposure from sediments by their food. Accumulation of nonylphenol in estuarine copepods could be a source to higher trophic levels, such as juvenile fish (Scott *et al.*, 2004). Endocrine disrupting effects have recently been observed in the hyperbenthic crustacean *Neomysis integer* in the Western Scheldt. (www.vliz.be/projects/endis). It can be concluded that apart from TBT-induced effects in snails our knowledge of endocrine disruption in invertebrates in the Wadden Sea is generally very limited (Gezondheidsraad, 1999).

4.7.2 Biological effect assessment techniques

4.7.2.1 Bioassay assisted assessment

Bioassays are laboratory tests with organisms that are exposed to a compound, mixture or environmental sample and give information on the effects of chemicals, chemical mixtures or known and unknown pollutants present in the environment. These tests are used for risk assessment of surface water, effluents, sediments and dredged material. Bioassays can be divided into *in vivo* and *in vitro* tests (Legierse, 2001). In *in vivo* bioassays organisms are exposed to compounds or samples under controlled conditions taking several days to weeks. They are used regularly for the ecological risk assessment of individual compounds and for the determination of environmental quality standards (Fan *et al.*, 1995; van Leeuwen and Hermens, 1995). Recently bioassays have been implemented in the assessment of environmental samples, such as dredged material (Stronkhorst *et al.*, 2003). *In vivo* bioassays can be subdivided into acute bioassays (short tests using criteria such as survival) and chronic bioassays (longer term tests, looking at more sensitive criteria such as reproduction, growth or behavior). Examples of commonly used marine and estuarine test organisms in bioassays are the bacterium *Vibrio fischerii* (MICROTOX Solid Phase), the amphipod *Corophium volutator*, the sea urchin *Echinocardium cordatum* and the polychaetous worm *Nereis virens*.

In vitro bioassays are quick tests (~28 hours) that use simple biological systems such as bacteria, cells or sub-cellular fractions. They are used as screening assays that provide an indication of possible detrimental ecological effects of compounds or mixtures. They can be subdivided into mechanism-based *in vitro* bioassays (reacting to a specific mode of action, such as the detection of endocrine disruption by binding to receptor sites) and broad-spectrum bioassays (reacting to different modes of action). Examples of commonly used toxicity mode of action assays are the general or acute toxicity (*Vibrio fischerii* in MICROTOX), dioxin-type toxicity (DR-CALUX), estrogenic activity (ER-CALUX) and genotoxicity (*Vibrio fischerii* in MUTATOX).

Bioassays of harbor sediments

In 1999-2000 a large number of harbors around the Dutch Wadden Sea were assessed for sediment quality (Stronkhorst *et al.*, 2003). The acute *in vivo* amphipod bioassay with *Corophium volutator* revealed that for 5 harbors the threshold of 24% mortality was exceeded (Table 4.7.2). This threshold is based on research experience and statistically based toxicity assessment criteria from the literature (*e.g.*, McGee *et al.*, 1999). For *C. volutator* such information is limited to a study in the vicinity of a North Sea oil platform where lower infaunal species diversity was associated with a 50 % mortality response in the *C. volutator* acute bioassay (Roddie and Thain, 2001).

According to the acute *in vivo* sea urchin (*Echinocardium cordatum*) bioassay, more than half of the harbor sediment samples tested were signifi-

Table 4.7.2: Results of different bioassays on dredged material from harbors in the Dutch Wadden Sea in 1999-2000. TU = Toxic Units (see text) (from: Stronkhorst *et al.*, 2003).

Harbour/bioassay	Number of samples	Test result	Percentage that exceed threshold of
Microtox Solid Phase		**Average TU**	**48 TU**
Delfzijl	13	32	31
Eemshaven	6	41	33
Lauwersoog	5	73	80
Wadden islands	13	31	31
Harlingen	18	50	50
Afsluitdijk	12	49	50
Den Helder	12	54	58
Corophium volutator		**Average % mortality**	**24% mortality**
Delftzijl	13	16	8
Eemshaven	5	23	40
Lauwersoog	1	13	0
Wadden islands	9	11	11
Harlingen	12	16	42
Afsluitdijk	6	13	0
Den Helder	5	8	20
Echinocardium cordatum		**% Mortality**	**35% mortality**
Delftzijl	13	51	62
Eemshaven	6	46	67
Lauwersoog	4	80	75
Wadden islands	13	43	54
Harlingen	18	53	78
Afsluitdijk	12	33	42
Den Helder	12	49	83

cantly toxic compared to the lower threshold limit for sea urchin mortality (Table 4.7.2). These are strong indications that the harbor sediments along the coast of The Netherlands are still contaminated. Because sea urchins are not always readily available, and mortality differences among replicates cause statistical problems, research has been started to culture the species in order to improve the (statistical) performance of this bioassay.

The results of the *in vitro* Microtox Solid Phase test show that on average more than 50% of the samples exceed the threshold of 48 Toxic Units (Table 4.7.2). The use of this bioassay to classify the ecological risks of harbor sediments was discussed and the conclusion drawn that for this purpose the applicability of the test needs further elucidation.

Bioassays of sediments and suspended matter

In a survey in 1999/2000 sediments from different locations in the Dutch Wadden Sea (in and outside harbors) were assessed with *in vitro* bioassays (Microtox SP and DR-CALUX) and *in vivo* bioassays using *Corophium volutator*, *Crassostrea gigas*, *Brachionus plicatilis* and *Echinocardium cordatum* (van den Brink and Kater, 2000) and experimentally using *Nereis virens* (Kater *et al.*, 2000). Mortality thresholds in *C. volutator* and *N. virens* and average responses were exceeded at a number of non-harbor locations. The results showed no significant correlation with the contaminant levels of PAHs, PCBs and metals measured in these sediments. Only organic tin compounds were significantly correlated with the Microtox SP and DR-CALUX response. Non-analyzed toxic compounds (*i.e.* mineral oil, organochlorine pesticides) or rather water soluble compounds might have shown better correlations.

Recently, *in-vitro* bioassay activity was measured in sediment or suspended matter extracts from locations along the Belgian-Dutch North Sea coast, the Wadden Sea and Ems estuary (Åkerman *et al.*, 2004). Some results presented in Figure 4.7.1 show relatively low estrogenic activity in the Wad-

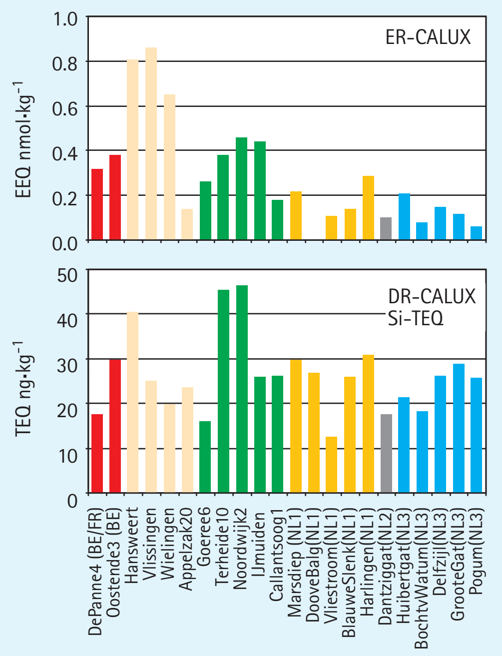

Figure 4.7.1: Typical Estrogenic activity (EEQ nmol kg^{-1} dry weight) by the ER-CALUX assay (top panel) and dioxine-type toxicity (TEQ ng kg^{-1} dry weight) by the DR-CALUX assay (lower panel) in suspended matter from the Belgian-Dutch North Sea coast, The Dutch Wadden Sea and Ems estuary, (source: Åkerman *et al.*, 2004).

den Sea and Ems estuary against high activity in the Western Scheldt. Dioxin-type toxicity does not show geographic differences.

Bioassays of water

Biological effect assessment of Dutch Wadden Sea water is reported by Åkerman and Smit (2003). In a pilot study with *in vitro* bioassays Microtox (for general toxicity), Mutatox (for genotoxicity) and ER-CALUX (for estrogenic activity) responses were found at several locations. The bioassays still need full validation for the water phase, but are considered a promising tool for the assessment of Wadden Sea surface water in the future.

4.7.2.2 TIE and EDA assisted assessment

Environmental anthropogenic contamination originates from numerous production, application and waste sources constituting a multitude of chemicals with intended or unintended effects on the biosphere. A relatively minute number of those chemicals, most of which have been recognized to be hazardous, are adopted in monitoring programs. From this view chemical monitoring alone is a poor approach for hazard assessment of the biosphere. This has been recognized in the Water Framework Directive, where the member states have to define both ecological and chemical targets. Not complying with either of the targets, however, does not elucidate the cause, and thus fails to indicate necessary measures in response. Nor does it shed light on the chronic risks from various anthropogenically elevated contaminant concentrations in the environment. Linking ecological effects and risk to chemical compounds is a prerequisite for establishing sustainable management of the environment. Effect Directed Analysis (EDA) offers functionality to link compounds to biological effects. This serves as a basis in the efforts to link (ecological) effects to their causative toxicants.

The principle of Effect Directed Analysis (EDA) and Toxicity Identification Evaluation (TIE) is to use the response in a biological (test) system to direct the chemical-analytical pathway towards identifying the compounds causing this response (Brack, 2003; Ankley *et al.*, 1991). The biological test systems are based on sets of bio-active structures responding to chemical compounds. At present they include tests with whole-organism *in-vivo* bioassays and cell-based *in-vitro* bioassays, and biochemical tests with biomarkers, biosensors and immunoassays, thus ranging from intact organisms to cell-free, bio-active cell components or molecules. Examples are described in section 4.7.2.1.

Ideally, a biological test system would respond to different (groups of) compounds, where the sequence of biological tests is sensitive enough to cover both a wide scope of biologically active chemical compounds as well as a wide range of pollution levels. Individual tests may, preferably, respond to a narrow range of compounds. In this way the EDA test battery and analytical sequence will respond to tracing back biological and ecological deteriorating effects due to its compound source. The chemical compounds identified by EDA can be denoted as 'key toxicants' and constitute the true priority compounds.

Additionally, the available chemo-analytical tools can, by concentrating the environmentally present compounds, boost the sensitivity of appropriate biological test systems to the level of ecological effect *prevention*.

In both aspects, hazard and risk, EDA is a useful tool in solving confounding factors in reaching the WFD targets such as 'good ecological status' from the key-toxicant view.

Once a biological response is recorded, indicating a potential or actual undesirable effect, the responsible compounds may be identified and counter measures designed. Measures derived this way should be more effective and thus more cost-effective than the current priority pollutant approach, which is usually based on correlation between effects and pollutant concentrations.

Several case studies of TIE and EDA reported in the literature were able to identify causative compounds with different degrees of certainty (Thomas *et al*, 1999; Burgess *et al.*, 2000; Hollert *et al.*, 2002; Pessala *et al.*, 2003; Klamer *et al.*, 2004). Klamer *et al.* (2004) could attribute ~ 50% of the dioxin-type toxicity in Wadden Sea harbour sediment, assessed with the DR-CALUX assay (Aarts *et al.*, 1993; Murk *et al.*, 1996), to dioxin-like compounds.

4.7.3 Environmental quality and flood events

The Elbe flooding event during August 2002 was expected to cause an increased input of contaminants to the Wadden Sea and subsequent concentration changes in the environmental matrices. Unexpectedly, hardly any changes in Elbe river input or concentrations were observed (Nies *et al.*, 2003). Exceptions were some increased contaminant levels in bird eggs (see section 4.4), increased concentrations of hexachlorobenzene, DDD and DDE in blue mussels and of cadmium and hexachlorobenzene in liver of flounder (see section 4.2).

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4.8 Final Remarks

Joop F. Bakker
Martine van den Heuvel-Greve
Dick Vethaak

4.8.1 Data management and quality assurance

Data management and quality assurance of chemical data (heavy metals and xenobiotics) in different matrices (except for bird eggs) is still a problematic issue in the Trilateral Monitoring and Assessment Program, which is rooted in existing national monitoring programs. On one hand, this ensures cost effectiveness, but on the other it hampers intercomparability of methods which were not well harmonized. During the preparation of this QSR problems were encountered regarding, for example, grain-size correction of concentrations in sediment, switched wet / dry weight data in blue mussels, and possible sample contamination.

It is therefore strongly recommended to regularly execute a thorough quality screening of Wadden Sea database data, based on the experiences of this QSR preparation and carried out by personnel trained to check chemical monitoring data.

4.8.2 Newly and politically emerging compounds

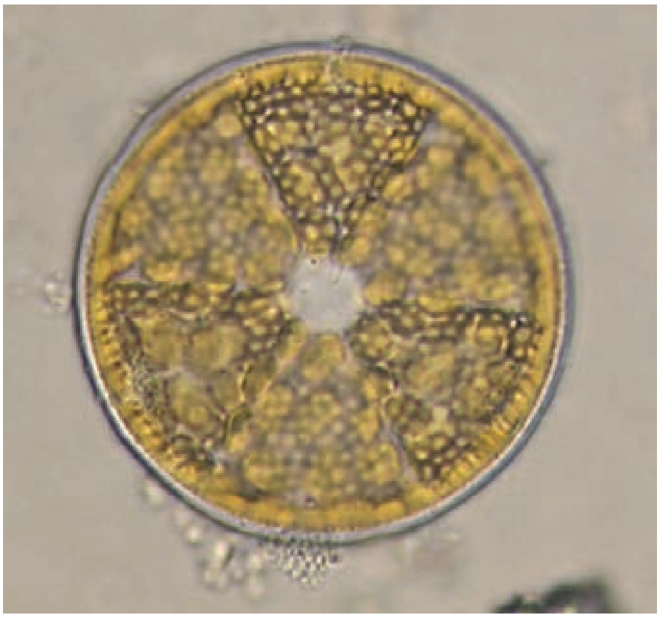
Newly and politically (*e.g.*, Water Framework Directive) emerging compounds are not yet part of the TMAP, while certain matrices may efficiently be analyzed for some of those compounds.

It is recommended to update the TMAP by considering additional chemical analyses in bird eggs, mussels, flounder and sediment, especially organotins, brominated flame retardants and perfluorinated surfactants. In risk assessments, the apparent bio-magnification at the level of lung-breathing organisms should be taken into account. Of course, harmonization of sampling, preparation and analytical methods should be given proper attention.

The current organization of monitoring of contaminants in bird eggs ('one-lab-approach') could be a source of inspiration.

In the Water Framework Directive compound levels negatively influencing the chemical and ecological targets are of priority importance. This demands a different type of assessment of chemical monitoring data, *e.g.* by looking for those locations where contaminant levels deviate from the average.

5. Eutrophication



Justus van Beusekom
Peter Bot
Jeanette Göbel
Michael Hanslik
Hermann-Josef Lenhart
Johannes Pätsch
Louis Peperzak
Thorkild Petenati
Karsten Reise

Diatom *Actinoptychus senarius* (Photo: J. v. Beusekom)

5.1 Introduction

Eutrophication is one of the factors that influence the quality of the Wadden Sea area. Since the earliest nutrient measurements in the Wadden Sea (Postma, 1954; Postma 1966; Hickel, 1989) a clear increase has been documented (*e.g.* de Jonge and Postma, 1974; Hickel, 1989; van Beusekom *et al.*, 2001). Among the negative effects associated with the increased nutrient loads are *Phaeocystis*-blooms (Lancelot *et al.*, 1987), a decline in seagrass (de Jonge and de Jong, 1992), increased blooms of green macroalgae (Reise and Siebert, 1994) and anoxic sediments ('black spots') (de Jong *et al.*, 1999).

A trilateral Target was adopted to aim for a Wadden Sea which can be regarded as a eutrophication non-problem area (Trilateral Wadden Sea Plan, 1997). The concept of the eutrophication problem and non-problem-areas has been developed in the framework of OSPAR (1997).

Target
A Wadden Sea which can be regarded as a eutrophication non-problem area

The following sections summarize the findings of the 1999 QSR (de Jong *et al.*, 1999), the results of a recent exercise to develop Wadden Sea specific eutrophication criteria and the results of the OSPAR Common Procedure in 2003. In the chapter 5.2 'Data analysis', recent trends in nutrient loads, nutrient concentrations and in phytoplankton and macroalgae biomass are described. A Target evaluation and recommendations are given. The present report updates and extends the data analysis of the 1999 QSR (de Jong *et al.*, 1999) and of the report on 'Wadden Sea Specific Eutrophication Criteria' (van Beusekom *et al.*, 2001).

5.1.1 Findings of the 1999 QSR

In the 1999 QSR trends in nutrient concentrations of the Wadden Sea were analyzed by Bakker *et al.* (1999) for the period 1985-1996. The authors noted that nutrient concentrations in the Wadden Sea during winter depend to a large extent on salinity. Therefore, actual concentrations cannot be directly compared unless they are standardized to a certain salinity. Details of the 'concentration – salinity' method are given in Bakker *et al.* (1999). The analysis in the 1993 and 1999 QSR (de Jong *et al.*, 1993; Bakker *et al.*, 1999) are based on winter concentrations normalized to standard salinities of 10 and 27.

The clearest decrease was observed for phosphate (PO_4, Dissolved Inorganic Phosphorus or DIP) which decreased by about 50% in most of the Wadden Sea. In the Dutch Wadden Sea winter phosphate concentrations of about 1 µM are observed, which gradually increase towards the estuaries of Weser and Elbe, where concentrations of 2-4 µM prevail. In the North Frisian and Danish Wadden Sea again concentrations of about 1 µM prevail.

No equivalent decrease was observed for nitrogen, although ammonium showed a clear downward trend in the Ems, Weser and Elbe estuaries, presumably due to the progressive imple-

The OSPAR Common Procedure

In 1997, the OSPAR Commission adopted the so-called 'Common Procedure' for the identification of the eutrophication status of the Maritime Area of the OSPAR Convention (OSPAR, 1997). The Common Procedure distinguishes three areas:

- 'Problem Areas' are those areas for which evidence of an undesirable disturbance to the marine ecosystem due to anthropogenic enrichment by nutrients exists
- 'Potential Problem Areas' are those areas for which there are reasonable grounds for concern that undesirable disturbance may occur
- 'Non-Problem Areas' are those for which such concerns do not exist.

The 'Common Procedure' consists of two steps, the 'Screening Procedure' and the 'Comprehensive Procedure' (COMP). The Screening Procedure identifies with a 'broad brush' approach those areas that are likely to be eutrophication Non-Problem Areas. It was not applied to the Wadden Sea because it was claimed to be at least a Potential-Problem Area. The Comprehensive Procedure identifies Problem Areas and Potential Problem Areas based on parameters from a 'holistic checklist' and if necessary based on region specific criteria. The latter were developed for the Wadden Sea by van Beusekom *et al.* (2001) and are grouped according to the Comprehensive Procedure below:

'Causative Factors' (Cat. I) are atmospheric and riverine nutrient input. The effect of the increased nutrient input is best seen in changes in the annual nutrient cycle.

'Supporting Factor' (Cat. II) for Wadden Sea eutrophication is the import of organic matter from the adjacent North Sea.

'Direct Effects' (Cat. III) of eutrophication could be observed in all biota of the Wadden Sea. However, no clear dose-response relation could be identified. Other factors like weather, temperature of more complex interaction also play important roles in the proliferation of eutrophication effects.

Indirect Effects such as changes in zoobenthos biomass and species composition were observed but no clear dose-response relation could be identified.

mentation and technical improvement of waste water treatment plants. Nitrate showed an upward trend in the western Dutch Wadden Sea and a downward trend in the Ems, Weser and Elbe estuaries. Winter nitrate concentrations in the Wadden Sea (27 psu) range between 20–110 µM but in most parts are about 50 µM. The 1999 QSR also stated that reductions in phosphate have not led to a reduction of biological phenomena which may be related to nutrient loading, notably average chlorophyll concentrations, the duration of *Phaeocystis* blooms in the Marsdiep and growth of macrozoobenthos. Although specific eutrophication criteria had not been developed by that time, the QSR 1999 concluded that the target had not yet been reached.

5.1.2 Wadden Sea specific eutrophication criteria

Recently, a literature study and data analysis was carried out aiming at developing Wadden Sea specific eutrophication criteria (van Beusekom *et al.*, 2001). The study was necessary to specify the trilateral Target 'to achieve a Wadden Sea which can be regarded as a eutrophication non-problem area'. The work was done in close cooperation with activities within the framework of the OSPAR Common Procedure through which relevant parts of the OSPAR Convention Area are designated as either non-problem, potential problem or problem areas with regard to eutrophication.

The literature review highlighted the importance of organic matter import from the North Sea for the Wadden Sea eutrophication. Statistical analysis of long term data from the Dutch Wadden Sea showed that high riverine input of TN (total nitrogen) enhances organic matter turnover as indicated by autumn values of N remineralisation products (NH_4, NO_2) in both the Rhine-influenced western part and in the North Sea-influenced eastern part of the Dutch Wadden Sea. It was proposed to use autumn values of N remineralisation products (NH_4+NO_2) as a measure of the eutrophication status.

In all Wadden Sea areas an increased eutrophication was observed from ~1960-1996. In both the southern Wadden Sea (Den Helder - Elbe) and in the northern Wadden Sea (Elbe - Esbjerg) primary production has increased. Whereas along the southern Wadden Sea variability of autumn values of N remineralisation products can be related to nitrogen input, no such relation is found in the northern Wadden Sea. Instead a possible relation between nitrate in the coastal zone and autumn values of N remineralisation products in the Sylt-Rømø Bight was found.

Two contrasting situations were postulated:

- the southern Wadden Sea with intense particle accumulation and a strong coupling of productivity and remineralisation with variations in nitrogen input via the Rhine and the Meuse and
- the northern Wadden Sea with less intense particle accumulation, where nutrient input from the west into the German Bight and not the Elbe river input determine primary production in the German Bight and consequently the organic matter import into the Wadden Sea.

Background concentrations of NH_4+NO_2 were proposed for the western Dutch Wadden Sea and amount to about 3 µM (situation in early 1930s). Accordingly, the present eutrophication status of the western Dutch Wadden Sea is on average 5 times higher than during the early 1930s. For the other Wadden Sea areas, background values were assigned based on present NH_4+NO_2 levels and assuming a similar increase in eutrophication status throughout the entire area. Based on the evaluation of eutrophication criteria, the Wadden Sea was assessed as a 'Eutrophication Problem Area'.

		The Netherlands	Germany	Denmark
Cat I:	Riverine Input (50% above background)	+	+	+
	Winter Concentrations	+	+	+
	Wadden Sea (>6-7 µM N)			
	Estuaries (>18-30 µM N)			
	N/P ratios	+	+	+
Cat II:	Chlorophyll levels (Max. >22-24 µg/l)	+	+	+
	Phytoplankton Indicator Species	+	+	-
	Macrophytes	+	+	+
Cat III:	Oxygen Problems	+	?	
	Changes/Kills of Macrobenthos	NK	?	-
	Changes in organic matter	+	?	-
Cat IV:	Algal toxins	+	+	+

Table 5.1: Summary of the Wadden Sea Eutrophication Assessment by OSPAR (OSPAR, 2003). All three Wadden Sea countries assessed the Wadden Sea as a Problem Area:'+' indicates that the assessment criterion was applied.

5.1.3 OSPAR eutrophication assessment

The whole OSPAR convention area was screened with the Common Procedure (see Box). The Wadden Sea was classified as a eutrophication problem area by Denmark, Germany and The Netherlands (OSPAR, 2003). As criteria, deviations from background levels were used. All three countries used nutrient enrichment, increased chlorophyll levels, problems with nuisance macroalgae and algal toxins as criteria. Differences and uncertainties in the assessment of the effects on macrobenthos and oxygen dynamics were apparent (Table 5.1).

5.2 Data analysis

5.2.1 Causative factors

5.2.1.1 River Input

Riverine input data is based on monitoring data that was interpolated to daily loads (Lenhart and Pätsch, 2001; updated until 2002). The major sources influencing the southern Wadden Sea are Haringvliet, Maassluis, Noordzeekanaal, IJsselmeer and Ems. The first sources are in a wider sense part of the Rhine - Meuse delta. Major sources for the central Wadden Sea (Jade - Eiderstedt) are the rivers Weser and Elbe. The latter rivers are also major nutrient sources for the northern Wadden Sea, where small rivers (Eider, Danish rivers) contribute about 6-7 %. The relative contributions of the above mentioned river sources are compiled in Table 5.2.

The high interannual variability of riverine nutrient input is largely due to two factors: differences in interannual freshwater discharge and a general decrease in nutrient concentrations. Figures 5.1–5.2 show that peaks in freshwater discharge coincide with peaks in nutrient loads. In general, the annual nutrient loads correlate significantly with the annual freshwater discharge. The correlation is much better for total nitrogen (TN) than total phosphorus (TP) (southern Wadden Sea: $r^2 = 0.62$ for TN and $r^2 = 0.37$ for TP; central Wadden Sea: $r^2 = 0.76$ for TN and $r^2 = 0.35$ for TP). Normalized nutrient loads (annual nutrient load divided by annual discharge) show a steady decreasing trend for TN and TP for the entire Wadden Sea (Figure 5.3). Since 1985 the specific TN load to the southern and central Wadden Sea decreased on average each year by 2.1-2.2%. The specific TP load decreased stronger than the specific TN load and amounted on average to 3.3% per year for the southern Wadden Sea and 2.5% per year for the central Wadden Sea.

Southern Wadden Sea			
Source	*Discharge*	*Total Nitrogen*	*Total Phosphorus*
Haringvliet	27.5%	27.2%	22.1%
Maassluis	47.4%	47.2%	57.2%
Noordzeekanaal	3.0%	2.9%	4.6%
IJsselmeer	19.3%	17.6%	13.8%
Ems	2.8%	4.6%	2.3%
Central and northern Wadden Sea			
Source	*Discharge*	*Total Nitrogen*	*Total Phosphorus*
Weser	31.1%	31.7%	30.1%
Elbe	62.0%	61.9%	64.3%
Eider	2.5%	2.2%	2.5%
County Ribe	3.4%	3.2%	2.1%
Jutland	0.9%	1.0%	0.9%

Table 5.2: Mean relative contribution of major fresh water sources to nutrient input into the southern (1977-2002) and central Wadden Sea (1980 to 2002). For the Eider and Danish rivers, data since 1990, resp. 1995 was used as reported to OSPAR (Data source: OSPAR, Umweltbundesamt).

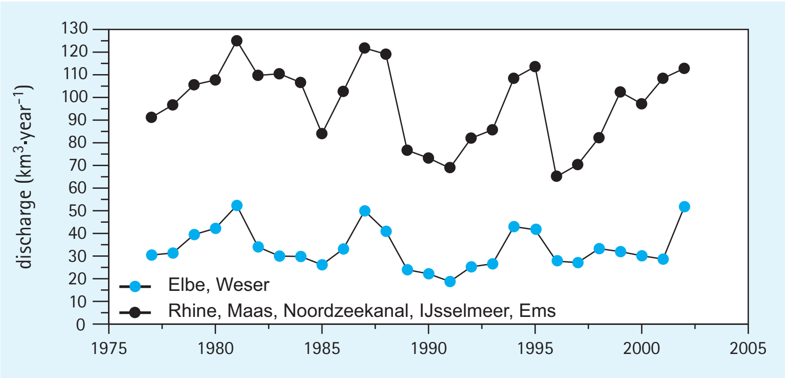


Figure 5.1: Major annual freshwater discharges influencing the southern Wadden Sea (Rhine, Meuse, Noordzeekanaal, IJsselmeer and Ems) and the central and northern Wadden Sea (Weser, Elbe). Data source: DONAR, Lenhart and Pätsch (2001).

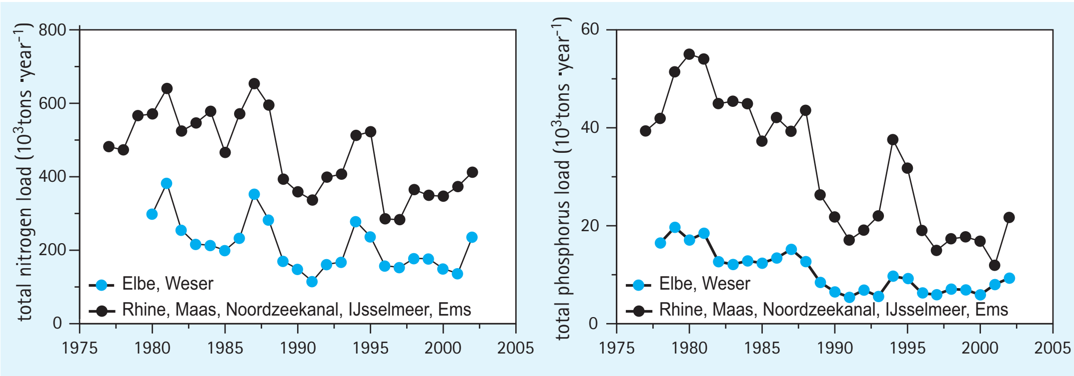


Figure 5.2: Major riverine TP and TN loads to the southern Wadden Sea (Rhine, Meuse, Noordzeekanaal, IJsselmeer and Ems) and to the central and northern Wadden Sea (Weser, Elbe). Data source: DONAR, Lenhart and Pätsch (2001).

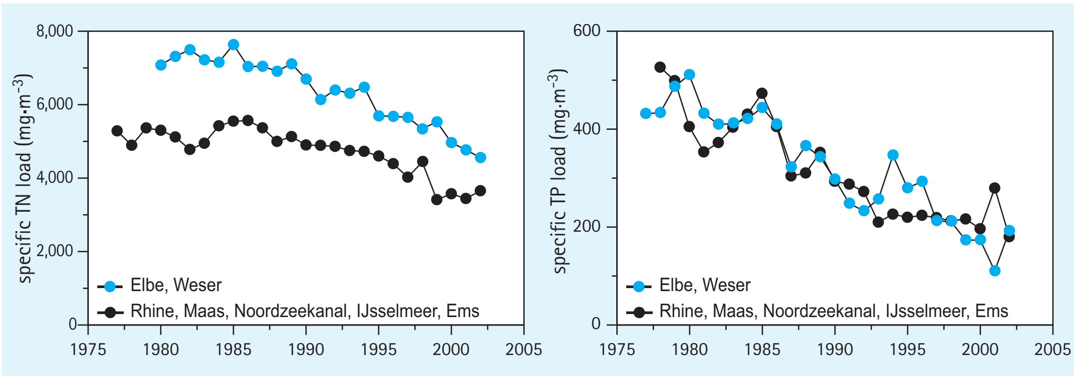


Figure 5.3: Specific nitrogen and phosphorus load (mean annual load / mean annual discharge) to the southern Wadden Sea (Rhine, Meuse, Noordzeekanaal, IJsselmeer and Ems) and to the central and northern Wadden Sea (Weser, Elbe). Data source: DONAR, Lenhart and Pätsch (2001).

5.2.1.2 Atmospheric Input

Van Beusekom *et al.* (2001) estimated a total (wet + dry) nitrogen deposition in the Wadden Sea of about 1.7 g N m^{-2} y^{-1}. Recent studies suggest a somewhat lower atmospheric deposition of about 1.2 g N m^{-2} y^{-1}: Model calculations predict a total atmospheric nitrogen deposition in the coastal North Sea of about 1 g N m^{-2} y^{-1} (de Leeuw *et al.*, 2001). Aertebjerg *et al.* (2002) indicate a total atmospheric deposition in the Danish Wadden of 1.2 –1.4 g N m^{-2} y^{-1}. OSPAR (2004) compiled time series around the North Sea. They mention an average wet deposition of 0.8 g N m^{-2} y^{-1} (total deposition: ~1.2 g N m^{-2} y^{-1}) with no trend. An estimated mean atmospheric N load of about 1.2 g N m^{-2} y^{-1} or 15.6 kT y^{-1} for the entire Wadden Sea shows that this atmospheric nitrogen input is comparable to the input of the Ems (*cf.* van Beusekom *et al.*, 2001).

5.2.1.3 Winter concentrations

Winter concentrations in the North Sea depend strongly on salinity (*e.g.* van Bennekom and Wetsteyn, 1990; Körner and Weichart, 1992). Monitoring data by the German Federal Maritime and Hydrographic Agency (BSH) reflects the gradual decrease in riverine nutrient input (van Beusekom *et al.*, 2004) and show a decrease of nitrate at a salinity of 30 from ~55 µM in 1978 to ~45 µM in 2000 – 2003 (actually, values for nitrate + nitrite were reported, but nitrite contributes only a small amount).

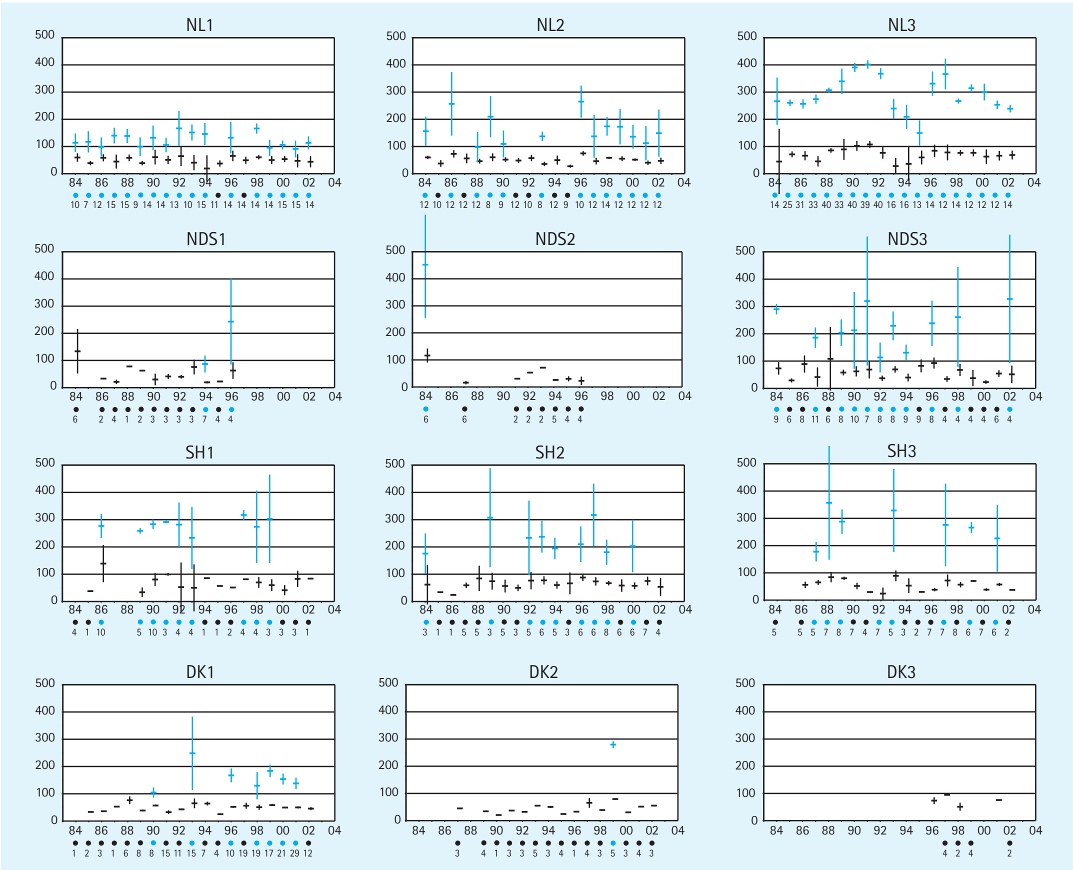


Figure 5.4: Trends in winter nitrate + nitrite concentrations (µmol/l) (December – February) in the 12 subareas of the Wadden Sea. The concentrations are normalized to a salinity of 10 (blue) and 27 (black). The horizontal lines represents the mean value, the vertical lines indicate the 95% confidence interval of the mean. Black dots: mean values based on salinity gradient. Blue dots: mean values (no significant salinity gradient). The numbers below the dots indicate the number of data used for the analysis. Data: TMAP Data Units.

Phosphate decreased in that period from ~2.5 µM to ~1.0 µM. Also in the Wadden Sea, winter nutrient concentrations correlate with salinity. In order to describe trends and to compare the different areas the winter concentrations were normalized to a salinity of 27. This estimate was only made if a significant correlation between nutrient concentrations and salinity was present. If not, the mean winter concentration was calculated. Details of this method are given in the 1999 QSR.

Figures 5.4 and 5.5 present updates of the QSR 1999 for nitrate (+ nitrite) and phosphate. Winter nitrate concentrations do not show a significant trend. Near estuaries the mean nitrate concentrations are somewhat higher (~65 µM) than in the other areas (~52 µM). Phosphate concentrations in winter did show a strong decrease from about 2 µM in 1985 to about 1.1 µM after 1995. Near estuaries the concentrations are higher and are at present ~ 2-3 µM.

5.2.2 Direct effects

5.2.2.1 Phytoplankton

Phytoplankton biomass and productivity

The analysis of chlorophyll data (an indicator of phytoplankton biomass) focuses on summer chlorophyll means (May-September) instead of annual means. The available data is summarized in Table 5.3. Long time series (15-27 years: Dutch Wadden Sea, Norderney, Sylt) that cover the entire seasonal cycle are shown in Figures 5.6 – 5.8.

Western Dutch Wadden Sea

Cadée and Hegeman (2002) summarize trends in phytoplankton biomass and productivity in the Marsdiep area (western Dutch Wadden Sea). They observed an increase in primary production from about 100-150 g C m^{-2} y^{-1} in 1965 to about 400 g C m^{-2} y^{-1} in 1994. Since then a decrease to values of about 200 g C m^{-2} y^{-1} has been observed. Mean annual chlorophyll levels decreased slightly.

The analysis of long-term phytoplankton composition in combination with nutrient budget data (Philippart *et al.*, 2000) suggested that the time series could be divided into three periods: a rich but phosphorus-controlled period (1974-1977), a more eutrophic, nitrogen-limited period (1978-1987) and a phosphate-limited period (1988-1993).

Mean summer chlorophyll-*a* levels (May-September) as observed by the Dutch Monitoring program amount to 18 µg Chl-*a*/l and are among

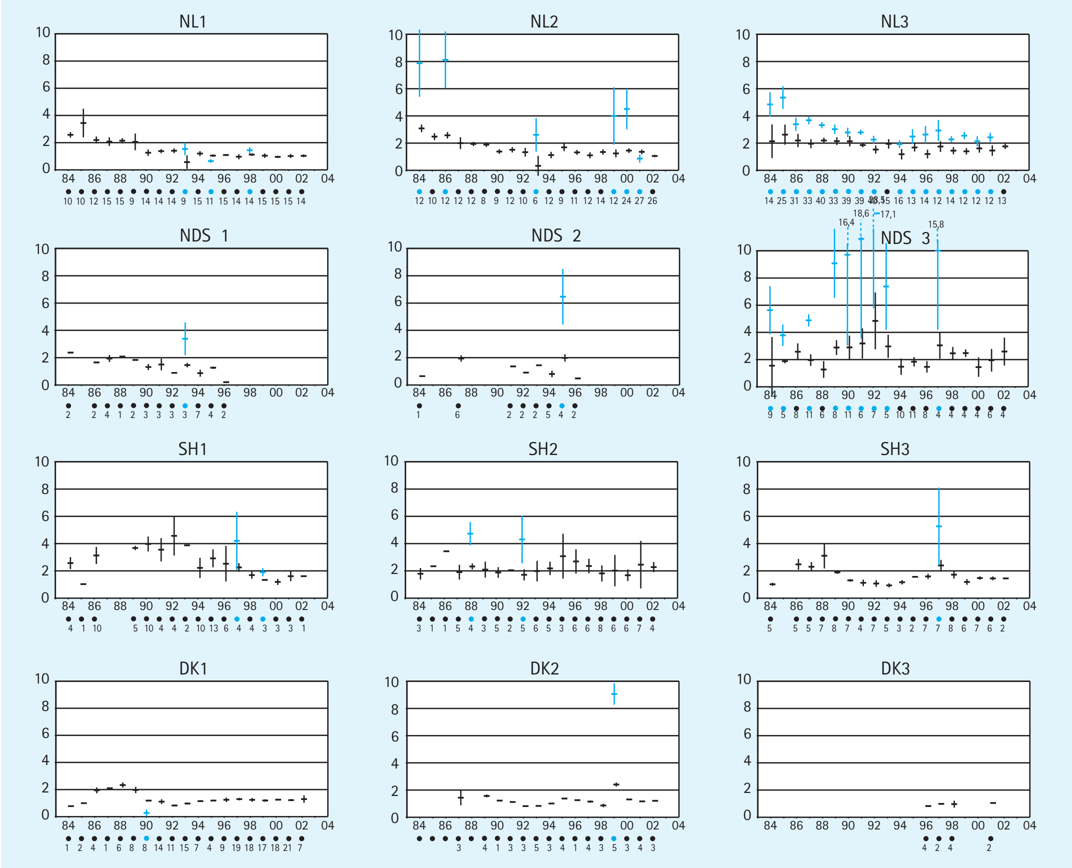


Figure 5.5: Trends in winter phosphate concentrations (µM) (December – February) in the 12 subareas of the Wadden Sea. The concentrations are normalized to a salinity of 10 (blue) and 27 (black). The horizontal lines represents the mean value, the vertical lines indicate the 95% confidence interval of the mean. Black dots: mean based on salinity gradient. Blue dots: mean values (no significant salinity gradient). The numbers below the dots indicate the number of data used for the analysis. Data: TMAP Data Units.

the highest in the Wadden Sea. They show a marked decrease from about 20 µg Chl-*a*/l in1976-1985 to about 11 µg Chl-*a*/l in 1996-2002.

Eastern Dutch Wadden Sea

Mean summer chlorophyll levels (May-September; Dutch Monitoring program) amount to 19.9 µg Chl-*a*/l and are the highest in the Wadden Sea. They show no decreasing trend.

Niedersachsen Wadden Sea

Mean summer chlorophyll concentrations at Norderney (~17 µg Chl-*a*/l) are lower than in the Dutch Wadden Sea. A decreasing trend from about 20 µg Chl-*a*/l around 1990 to ~15 µg Chl-*a*/l during the last five years has been observed.

Schleswig-Holstein Wadden Sea

Summer chlorophyll concentrations in the northern Wadden Sea are lower than in the southern Wadden Sea. A clear spatial gradient is present showing higher chlorophyll concentrations (~14 µg Chl-*a*/l) near the Elbe-Weser estuary decreasing to 6.3 µg Chl-*a*/l in the Sylt Rømø Bight. Only in the latter area, a decreasing trend is observed that correlates with TN loads from the Rhine/ Meuse and Elbe/Weser.

Danish Wadden Sea

Summer chlorophyll concentrations in the Danish Wadden Sea are about 8.6 µg Chl-*a*/l. No temporal trends or correlations with riverine input could be identified.

Spatial Trends

Summer levels in the southern Wadden Sea are about twice as high as in the central and northern Wadden Sea (Table 5.3). The highest levels are near the major nutrient sources (Dutch Wadden Sea: IJsselmeer. Southern Schleswig-Holstein Wadden Sea: Weser and Elbe) and decrease with increasing distance from the estuaries. The latter gradient is clearer in the northern Wadden Sea.

Relation with nutrient input

Relations with riverine nutrient input (Table 5.3) were identified for the western Dutch Wadden Sea, for Norderney (Niedersachsen Wadden Sea) and for the Sylt Rømø Bight (northern Wadden Sea). We chose the TN input via Rhine and Meuse as a common driver that possibly reflects Europe-wide climatic and agricultural trends (see below) In all cases a significant correlation ($p<0.01$) existed with the TN input during December (previous year) until August. The same time window was used in

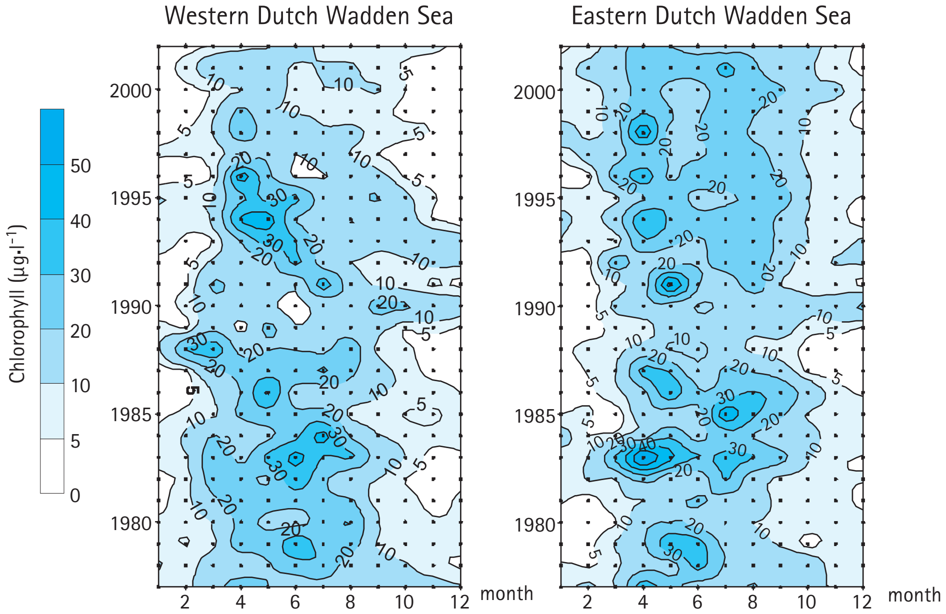
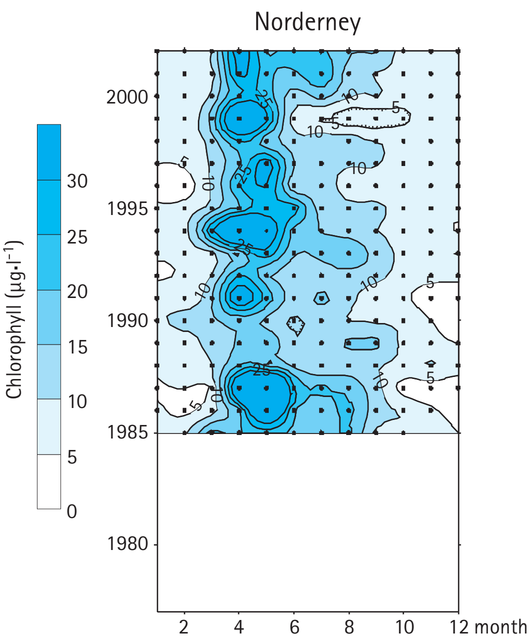


Figure 5.6: Seasonal cycle of chlorophyll in the western and eastern Dutch Wadden Sea, 1977-2002. Data: TMAP Data Units and DONAR.



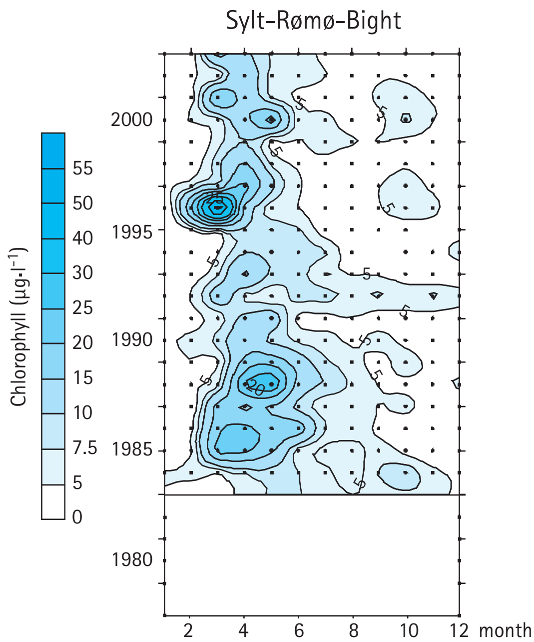


Figure 5.7 (left): Seasonal cycle of chlorophyll in the Niedersachsen Wadden Sea (Norderney), 1985-2002. Data: TMAP Data Units and NLÖ (M. Hanslik).

Figure 5.8 (right): Seasonal cycle of chlorophyll in the North Frisian Wadden Sea (Sylt-Rømø-Basin), 1983-2003. Data: TMAP Data Units and AWI (J. van Beusekom).

the eutrophication criteria study (van Beusekom *et al.*, 2001). In all cases, about 1/3 of the variability was explained by TN input. Interestingly, the relative influence of the riverine TN load on the chlorophyll levels (regression coefficient/ long-term mean chlorophyll) was similar for all sites (Table 5.3).

These results indicate that summer chlorophyll might be used as a eutrophication indicator. Using TN input via Rhine and Meuse does not necessarily imply that other sources are not important. The 'statistical significance' of the correlation with the Rhine/Meuse time-series is probably related to the size of this river system, reflecting both the general precipitation pattern over North Western Europe and Europe-wide changes in the use of fertilizers, implementation of water treatment plants, changes in land use and burning of fossil fuels. It should be noted that the temporal patterns in the Rhine-Meuse system are very similar to the patterns in the Weser-Elbe-system (Figure 5.1 – 5.3). In fact, TN and TP loads of both systems are significantly correlated (TN: r^2=0.76; p<<0.00001; N=23, TP: R^2=0.81; p<<0.00001; N=25).

Table 5.3:
Comparison of summer chlorophyll levels (µg/l; May-September) in different parts of the Wadden Sea and their correlation with TN input via Rhine and Meuse. In the case of a significant correlation a factor relating riverine input with chlorophyll levels is given. This factor is the slope of the regression multiplied by 10^6 divided by the mean chlorophyll level. The ‚statistical significance' of the correlation with the Rhine/Meuse time-series is probably related to the size of this river system, reflecting both the general precipitation pattern over Northwestern Europe and Europe-wide changes in the use of fertilizers, implementation of water treatment plants, changes in land use and burning of fossil fuels. Data source: TMAP Data Units, DONAR, LANU (J. Göbel), NLWKN (M. Hanslik), AWI (van Beusekom), Lenhart and Pätsch (2001).

Area	Period	Mean	Trend/Factor	Correlation and significance		
Western Dutch Wadden Sea	1976-2002	18.0	Yes/2.7	r^2=0.43	n=27	p=0.0002
Eastern Dutch Wadden Sea	1976-2002	19.9	No Trend			
Niedersachsen Wadden Sea (Norderney)	1988-2002	16.6	Yes/2.1	r^2=0.308	n=18	p=0.008
Southern Schleswig-Holstein	1990-2002	14.2	No Trend*	r^2=0.002	n=13	p=0.868
Northern Schleswig-Holstein	1990-2002	7.4	No Trend*	r^2=0.12	n=13	p=0.245
Sylt-Rømø-Bight	1984-2002	6.3	Yes/2.7	r^2=0.345	n=19	p=0.008
Danish Wadden Sea	1990-2002	8.6	No Trend*	r^2=0.18	n=12	p=0.15

*Also no trend with Elbe/Weser Input (Jan. - August).

Toxic and nuisance blooms

Dutch Wadden Sea

The duration of *Phaeocystis* blooms in the Marsdiep area decreased from a maximum of about 140 days during the early 1990s to about 60 days in 2000 (Phillipart *et al.*, 2000). Data from the Dutch monitoring program shows that since 1996, *Phaeocystis* sp. bloomed (>10^6 cells/l) between 68 and 33 days.

Since the 1999 QSR, some toxic blooms were observed: *Fibrocapsa japonica* bloomed once during 2001 (>10,000 cells /l), but no negative effects were reported. *Dinophysis acuminata* bloomed (>100 cells/l) 29 days during 2001 and 23 days during 2002. These blooms caused increased DSP (diarrhetic shellfish poisoning) levels in mussels.

Niedersachsen Wadden Sea

Some conspicuous blooms were observed. In September 1999 the dinoflagellate *Prorocentrum redfieldii* reached up to 320,000 cells/l between Spiekeroog and Wangerooge. Critical cell numbers of the dinoflagellate *Dinophysis* spp. were observed in late summer 1997, 2000, 2001 and 2002 and harvesting of mussels was temporarily stopped.

Schleswig-Holstein Wadden Sea

The most conspicuous blooming alga was *Chattonella*. This alga was responsible for fish kills in Danish and Norwegian waters in 1998. In that year the southern limits of the bloom were northwest of Sylt, where up to 0.17 Mio cells/l were observed. In May 2000, a *Chattonella* bloom reached up to 10^6 cells/l northwest of Sylt. No negative effects were observed in this part of the Wadden Sea. A major *Phaeocystis* bloom was observed in 2000. Toxic dinoflagellates (*Dinophysis* spp., *Alexandrium tamarense*) were regularly observed. In 1998, shellfish harvest was temporarily stopped south of Sylt. In 1999 up to 1000 cells/l were observed near Sylt - but without toxic effects.

Danish Wadden Sea

An overview of potentially toxic blooms was given by Aertebjerg *et al.* (2003). *Phaeocystis* blooms occurred each year along the Danish West coast (major bloom in 2000). The potentially toxic *Chattonella* bloomed along the Danish coast in 1998, 2000 and 2001. These blooms were accompanied by fish kills. *Karenia mikimotoi* (*Gyrodinium aureolum*) bloomed in 1997 accompanied with dead benthic invertebrates. *Prorocentrum micans* bloomed in 1997 and 1999. In 1999 DSP was found in shellfish. No toxic blooms were observed in 2002 and 2003 (Amterne Vadehavssamarbejde, 2003, 2004).

5.2.2.2 Macroalgae

Compared to rocky shores, macroalgae used to cover sediments only to a minor extent. However, from the late 1970s to 1980s green algae started to occur in thick mats covering vast areas of tidal sediments in the Wadden Sea (Reise, 1983; de Jonge *et al.*, 1993; Reise and Siebert 1994; Kolbe *et al.*, 1995) as well as in coastal areas elsewhere in the world (Fletcher, 1996). This development peaked in 1990-1993 with algal mats covering up to 20% of the intertidal area in the German Wadden Sea. Since then green algae remained abundant and thick mats occurred locally but never regained the massive proportions of the early 1990s. The summer of 2004 was the first with green algae returning back to their marginal occurrences prior to the 1980s. A monthly assessment of green algal mass at a site near Sylt, where no green algae occurred in the 1970s and earlier,

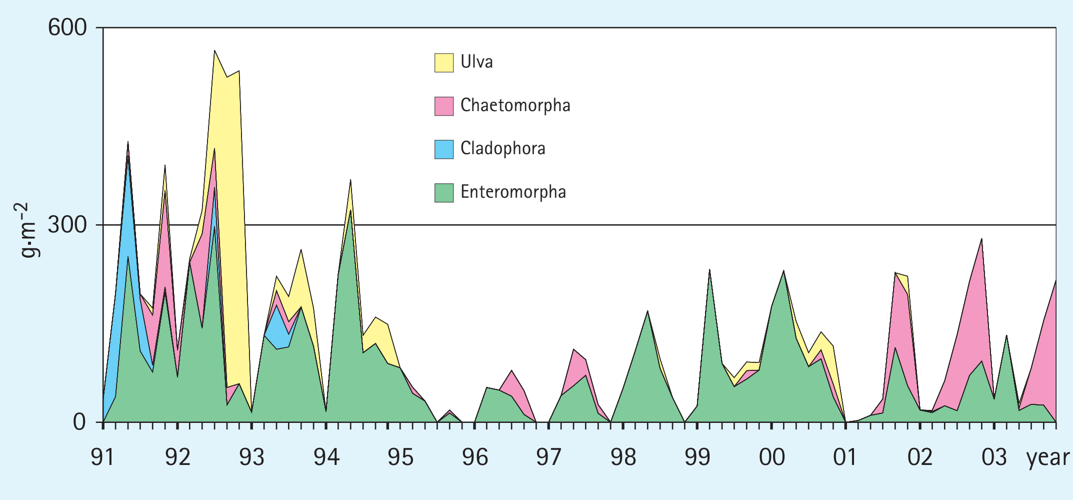


Figure 5.9: Phytomass (g organic dry weight per m²) of green algal genera at a site in Königshafen near Sylt in the northern Wadden Sea, measured monthly from May to October on an area of 2500 m² between 1991 and 2003 (Reise, unpubl.).

reflects fairly well the general development throughout the 1990s and to the present (Figure 5.9). Interannual and seasonal fluctuations are large, filamentous *Enteromorpha* tend to dominate but occasionally other green algae achieve dominance. The sediment underneath algal mats turned anoxic, benthic animals escaped or died, and suffocated seagrass decayed.

Although massive green algal developments have been generally related to coastal eutrophication (Fletcher, 1996), there is no apparent spatial or temporal relation of this phenomenon to riverine nitrogen or phosphorus loads into the Wadden Sea. As several taxa of green algae are involved, a general cause or combination of causes is likely which may involve remineralisation rates and turbidity at the tidal flats, temperature and turbulence, nutrient competition with phytoplankton or grazing by invertebrates.

5.2.3 Indirect effects

5.2.3.1 Autumn NH_4+NO_2 as indicator of organic matter turn-over

In the report on 'Wadden Sea Specific Eutrophication Criteria' (van Beusekom *et al.*, 2001) it was suggested to use the intensity of the seasonal cycle of NH_4+NO_2 (more specifically, the autumn values) as an indicator of the organic matter turnover in the Wadden Sea. The seasonal cycles of the major component NH_4 are shown in Figures 5.10 - 5.12 for the Dutch Wadden Sea, the Niedersachsen Wadden Sea (Norderney) and the North Frisian Wadden Sea (Sylt). The analysis for the Dutch Wadden Sea was based on a multiple regression with mean autumn NH_4+NO_2 concentrations as the dependent variable and riverine TN input, autumn chlorophyll levels and temperature as independent variables.

We repeated the analysis for the Dutch Wadden Sea and for Norderney. The results confirm that the autumn values are good eutrophication indicators for the southern Wadden Sea. NH_4 and NO_2 concentrations in the Dutch Wadden show a gradual decrease in the Western part, but trends in the eastern part are less obvious. Nevertheless, in both parts of the Dutch Wadden Sea, the riverine total nitrogen input (December-August) was significantly correlated with the autumn NH_4+NO_2 levels (Table 5.4). Chlorophyll did not significantly influence the relation in the western Dutch Wadden Sea, but had a major impact in the eastern part. For the Niedersachsen Wadden Sea (Norderney) a significant partial correlation exists between the Rhine-Meuse TN input and autumn NH_4+NO_2 concentrations (years 1986-2001). The overall multiple correlation is not significant.

In contrast to the southern Wadden Sea, the autumn NH_4+NO_2 concentrations in the North Frisian Wadden Sea (Sylt) show an increasing trend suggesting an increased eutrophication status. NO_3 concentrations in autumn, however, show a decreasing trend (significantly correlated with the TN load via Rhine and Meuse). This suggests that autumn values of NH_4+NO_2 are not good indicators of organic matter turnover in the northern Wadden Sea. On the other hand, the lower NH_4+NO_2 values and lower summer chlorophyll levels in the northern Wadden Sea are in line with a generally lower eutrophication status of the northern Wadden Sea.

Figure 5.10: Annual and seasonal ammonium cycle in the Dutch Wadden Sea. Data: TMAP Data Units and DONAR.

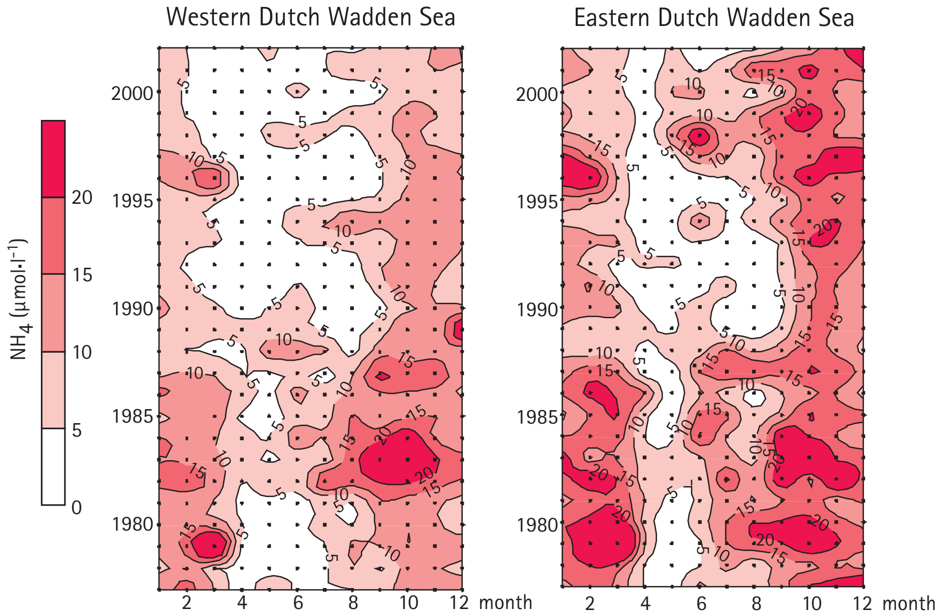


Figure 5.11 (left): Annual and seasonal ammonium cycle in the Niedersachsen Wadden Sea (Norderney). Data: TMAP Data Units and NLÖ (M. Hanslik).

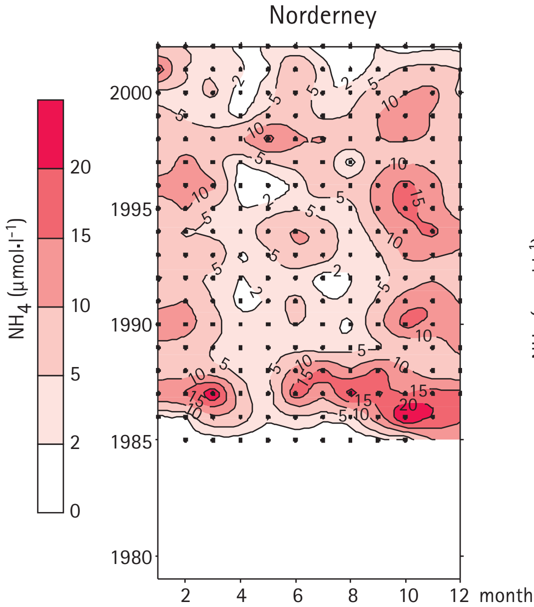
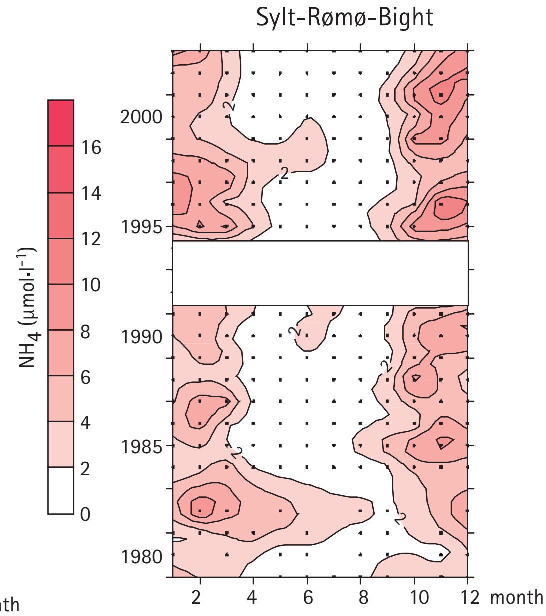


Figure 5.12 (right): Annual and seasonal ammonium cycle in the North Frisian Wadden Sea (Sylt Rømø Bight). Data: TMAP Data Units and AWI (J. van Beusekom).



5.2.4 Effects of decreased nutrient input

Within the framework of the Dutch EVA-II project evaluating the effects of shellfish fishery a model study was carried out on the effects of decreased riverine nutrient inputs in the western Dutch Wadden Sea (Brinkman and Smaal, 2003). The model showed a response in the form of decreased primary production, and therefore a decreased carrying capacity for filter feeding bivalves. Good field data for filter feeders, however, is not available to prove or refute the outcome of the model.

5.2.5 Target evaluation

Targets on the chemical quality of the Wadden Sea ecosystem aim at natural levels of nutrient concentrations and nutrient input. They are prerequisite for a naturally developing phytoplankton and phytobenthos.

Background concentrations of NH_4+NO_2 in autumn as a proxy of organic matter turnover in the Wadden Sea have been estimated at about 3 µM for the western Dutch Wadden Sea (van Beusekom *et al.*, 2001; van Beusekom, 2005). Background TN concentrations of about 45 µM (~0.6 mg/l) for rivers entering the North Sea have been estimated by Laane (1992) being about 7-8 times lower than present values of about 4-5 mg/l (Figure 5.3, left panel).

Riverine nutrient input shows a gradual decrease and the Wadden Sea ecosystem is responding: In several areas, summer chlorophyll levels and the intensity of organic matter turnover (using NH_4+NO_2 as a proxy) decrease and correlations with riverine nutrient input exist. The combination of dry years (low nutrient loads) and decreasing TN concentrations in the rivers Rhine and Meuse have lead to rather low TN loads during the 1990s. Still, NH_4+NO_2 levels are about 50% higher than those observed during the 1960's and about three times higher than under non-problem conditions (Table 5.5).

No background values for nutrients have been specifically deduced here for the other parts of the Wadden Sea or the North Sea coast because little reliable data exists from a time of low anthropogenic influences (OSPAR, 2000; Bakker *et al.*, 1999).

As a first approximation it can be assumed that all Wadden Sea areas have a similar relative deviation from pristine conditions as in the western Dutch Wadden Sea (Table 5.5; compare van Beusekom *et al.*, 2001). Comparing the background estimates with recent values shows that the entire Wadden Sea is a 'Eutrophication-Problem-Area' with present levels being three to five times higher than under pre-industrial conditions. This implies that the target has not been reached yet.

Western Dutch Wadden Sea (1977-2002)				
Dependent:	Sum of NH_4 and NO_2 (Month 9-11)			
Independent:	Rhine/Meuse TN load (Month 12-8)			
Covariable:	Chlorophyll (Month 9-11), Temperature (Month 9-11)			
	Results			
	N=26	p=0.00078	R^2=0.53	Outlier: none
	Variable	Beta	B	P
	TN load	0.66	0.00005	0.0003
	Chl a	-0.11	-0.15	0.46
	Temp	0.14	0.77	0.238
	One outlier identified. Omission would increase R^2 from 0.53 to 0.56			

Eastern Dutch Wadden Sea (1977-2002)				
Dependent:	sum of NH_4 and NO_2 (Month 9-11)			
Independent:	Rhine/Meuse TN load (Month 12-8)			
Covariables:	Chlorophyll (Month 9-11), Temperature (Month 9-11)			
	Results			
	N=26	p=0.0081	R^2=0.408	Outlier: none
	Variable	Beta	B	P
	TN load	0.36	0.00003	0.045
	Chl a	-0.40	-0.62	0.029
	Temp	0.20	1.16	0.25
	No outliers identified.			

Niedersachsen Wadden Sea (1986-2001)				
Dependent:	sum of NH_4 and NO_2 (Month 9-11)			
Independent:	Rhine/Meuse TN load (Month 12-8)			
Covariables:	Chlorophyll (Month 9-11), Temperature (Month 9-11)			
	Results			
	N=16	p=0.15	R^2=0.346	Outlier: none
	Variable	Beta	B	P
	TN load	0.60	0.00003	0.029
	Chl a	-0.23	-0.47	0.36
	Temp	-0.20	-0.96	0.44
	No outliers identified.			

Table 5.4: Results of the multiple regression between TN input via Rhine and Meuse and the N remineralisation in the Wadden Sea.

5.3 Conclusions

5.3.1 Main Results

The main results are grouped according to the categories used in the OSPAR 'Comprehensive Procedure'.

5.3.1.1 Category I: Nutrients

Riverine nutrient input showed a gradual decrease during the period 1997-2002. This is reflected by the phosphate concentrations in winter in the Wadden Sea that decreased since the mid 1980's to winter levels of about 1 µM. Salinity normalized nitrate + nitrite concentrations in the German Bight in winter reflect the decreasing TN load, but in the Wadden Sea proper no consistent trend is yet detectable.

5.3.1.2 Category II: Direct effects on primary producers

The decreasing nutrient input (TN loads by Rhine and Meuse) had a significant effect on the phytoplankton biomass (as chlorophyll) in summer in most of the southern Wadden Sea. In the northern Wadden Sea a less clear picture emerges. Only in the Sylt-Rømø-Bight, decreasing summer chlorophyll levels correlate with riverine TN input.

Toxic blooms are observed in all parts of the Wadden Sea, but no increasing trend or relations with nutrient input are evident. The most conspicuous blooms were observed in 1998 and 2000 along the Danish west coast, and were large, ichthyotoxic *Chattonella* blooms. The main nuisance blooms were due to *Phaeocystis*. Long-term data from the Marsdiep (western Dutch Wadden Sea) shows a decreasing trend in bloom duration. Present macroalgae abundance is below the maximum levels observed during the early 1990s.

5.3.1.3 Category III: Direct effects on organic matter

The decreasing nutrient input (TN loads by Rhine and Meuse) had a significant effect on the autumn NH_4+NO_2 values in the southern Wadden Sea. The autumn NH_4+NO_2 values are a good indicator of organic matter turnover in the southern Wadden Sea.

In the northern Wadden a less clear picture emerges. In the Sylt-Rømø-Bight an increasing trend of autumn NH_4+NO_2 values was observed suggesting an increased organic matter turnover but a decreasing trend in autumn NO_3 values was

Table 5.5:
Classification of the Wadden Sea into Non-Problem, Potential Problem and Problem Areas based on autumn concentrations of NH_4+NO_2 (µM) as proposed by van Beusekom *et al.* (2001) and modified with data from the recent study. The division into sub-regions is based on the availability of seasonal data. The present autumn values refer to values during the period 1997-2002. Non-problem conditions were based on background values for the western Dutch Wadden Sea. Values for the other areas are proportionally assigned on the basis present day values (1997-2002). Values for the Sylt Rømø Bight are based on the measured data and not calculated as in the table presented by van Beusekom *et al.* (2001). All threshold values were formally derived and an uncertainty range of ± 1µM should be added.

Area	Non-Problem conditions	Potential Problem conditions	Problem conditions	'Present' values (1997-2002)
Western Dutch Wadden Sea	<3.0 µM	3.0 µM <> 8.3 µM	> 8.3 µM	9.9 µM
Eastern Dutch Wadden Sea	<4.0 µM	4.0 µM <> 10.2 µM	> 10.2 µM	19.8 µM
Niedersachsen Wadden Sea	<3.2 µM	3.2 µM <> 8.2 µM	> 8.2 µM	10.1 µM
Sylt Rømø Bight	<1.9 µM	1.9 µM <> 4.2 µM	> 4.2 µM	6.1 µM
Danish Wadden Sea	<2.5 µM	2.5 µM <> 6.5 µM	> 6.5 µM	10.2 µM

observed that correlated with TN input. Data from the other parts of the northern Wadden Sea did not reveal any trends.

5.3.1.4 Regional differences

The data analysis highlights regional differences in Wadden Sea eutrophication. In general, the summer phytoplankton biomass and the autumn NH_4+NO_2 values in the southern Wadden Sea are about twice as high as in the northern Wadden Sea. This suggests a more intense eutrophication of the southern Wadden Sea. The reason for this fundamental difference is not yet known, but a possible relation with a more efficient particle accumulation in the southern Wadden Sea has been proposed (van Beusekom *et al.*, 2001). The geographical distribution of phytoplankton biomass reflects the importance of nutrient loads as higher values are observed near the main freshwater sources (Rhine-Meuse-IJsselmeer and Elbe-Weser).

5.3.1.5 Background values

Compared to background TN concentrations of about 45 µM (~0.6 mg/l) in rivers entering the North Sea (Laane, 1992) present day mean TN values of 4-5 mg/l are about 7-8 times higher. The present day organic matter turnover rates in the Wadden Sea (as indicated by NH_4+NO_2 values) are about 3-5 times higher than the rates expected with background riverine TN loads (Table 5.5). Van Raaphorst *et al.* (2000) estimated a background TN concentration in the Wadden Sea of 17 µM, being 6-7 times higher than present TDN (Total Dissolved Nitrogen) values. Brockmann *et al.* (2004) developed background values of TN and chlorophyll-*a* for the German Bight. They found about 3-5 times higher TN and chlorophyll levels in the Wadden Sea as compared to pristine conditions.

5.4 Recommendations

5.4.1 Management

The target of a Wadden Sea without eutrophication problems has not yet been reached. Therefore it is recommended continuing to implement current policies to reduce nutrient input, especially with regard to nitrogen compounds.

5.4.2 Monitoring and research

5.4.2.1 Comparison between the northern and southern Wadden Sea

The present study reveals some fundamental differences between the southern and northern Wadden Sea: In the southern Wadden Sea summer chlorophyll levels are found twice as high as in the northern part despite similar winter nutrient concentrations. NH_4+NO_2 also reach about two times higher levels in the southern parts compared to the northern parts. Also, suspended matter concentrations in the southern Wadden Sea are higher than in the northern Wadden Sea. A possible explanation is that the southern Wadden Sea accumulates suspended matter and organics more efficiently. Research directed towards understanding the differences between the northern and the southern Wadden Sea should be supported.

5.4.2.2 Exchange rates with the North Sea

In order to compare nutrient concentrations in the different parts of the Wadden Sea, especially if they are locally produced (such as NH_4 or NO_2) the residence time of water in different tidal basins should be known. Up to now, no estimates of residence times have been calculated for the entire Wadden Sea using the same methodology or model data.

5.4.2.3 Influence of filter feeders: in particular of new invaders

The present study suggests that summer chlorophyll levels may be used as an indicator of the eutrophication status because of the significant correlation with riverine nutrient input in some areas. In order to use this parameter as an assessment criterion, the role of suspension feeders in the summer chlorophyll dynamics should be investigated. Special emphasis should be directed toward invaders. *Crassostrea* and *Crepidula* are invaders, important filter feeders and recent trends towards warmer winter and summers suggest an enhanced spread (Diederich *et al.*, 2005; Thieltges *et al.*, 2004). Also, meroplankton data from the northern Wadden Sea shows an enhanced occurrence of larvae from *Ensis americanus* (M. Strasser, pers. comm.). It therefore remains an open question whether the recent decline in summer chlorophyll levels is due to a decreased riverine nutrient input or to increased filtration rates.

5.4.2.4 Importance of coverage of the entire seasonal cycle

The present study was based on nutrient and chlorophyll data that covers the entire annual cycle with a resolution of at least once a month and preferably more frequently during the growth season in order not to miss peaks in chlorophyll abundance. Not all monitoring programs have the necessary temporal resolution. Care should be taken that also in the future such data is available and that temporal and spatial resolution of monitoring programs is extended.

5.4.2.5 Residual nutrient potential in sediments

In order to estimate how fast the Wadden Sea can adapt to decreasing nutrient loads, the nutrient release from Wadden Sea sediments, especially from buried organic matter in deeper sediment layers, should be assessed.

5.4.2.6 Oxygen dynamics

The use of daily oxygen dynamics (production during the day, remineralisation during day and night) as an indicator of organic matter dynamics should be explored. Commercial sensor packages are available that guarantee a long stability of the sensors.

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6. Introduced Species

Karsten Reise
Norbert Dankers
Karel Essink

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 diatoms *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 *Campylopus 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	
		Atlantic	Pacific	ship	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
Ascidiacea	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 C_4 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 m^2, 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 including 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)

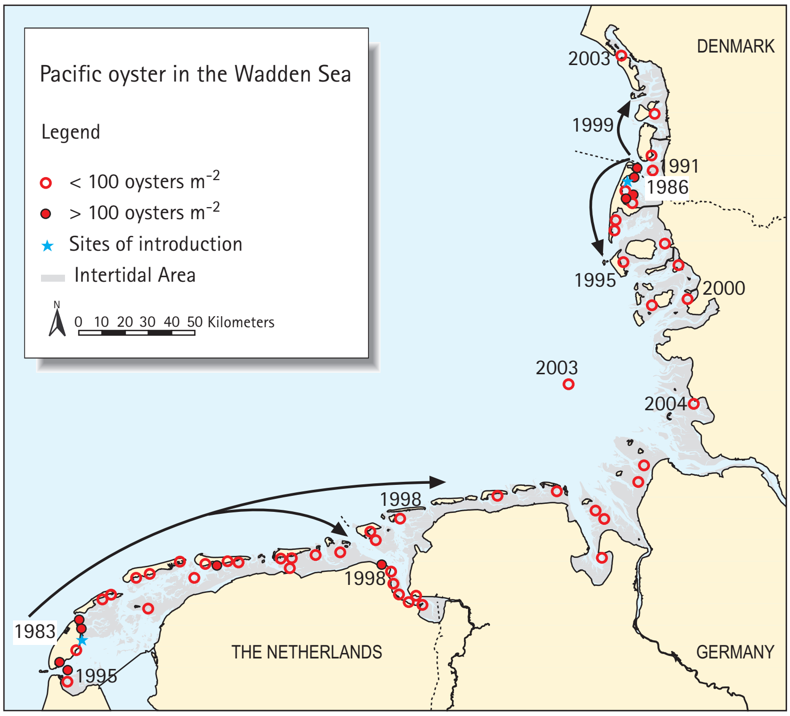

Figure 6.1: The Pacific oyster *Crassostrea gigas* in the Wadden Sea. Asterisks indicate sites and years (boxed) of introduction (Texel, Sylt). Other years indicate first records of settlement by larval dispersal for selected sites. Circles show mean abundance in 2003.

their habitat from oyster to mussel beds and locally form monospecific epibenthic assemblages with limpets attached to each other (Thieltges *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 (Thieltges *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 (Thieltges, 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 roscovita* 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 introductions, effective precautionary measures are in need (Nehring and Klingenstein, 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 Klingenstein, 2005).

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7. Salt Marshes

Jan P. Bakker
Jürn Bunje
Kees Dijkema
John Frikke
Norbert Hecker
Bas Kers
Peter Körber
Jörn Kohlus
Martin Stock

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 (Meltofte *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 development 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	Niedersachsen*	Hamburg	Schleswig-Holstein	Denmark**	TOTAL
Years	1995-2002	1997	1995-1998	2001-2002	1995-2000	
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'.

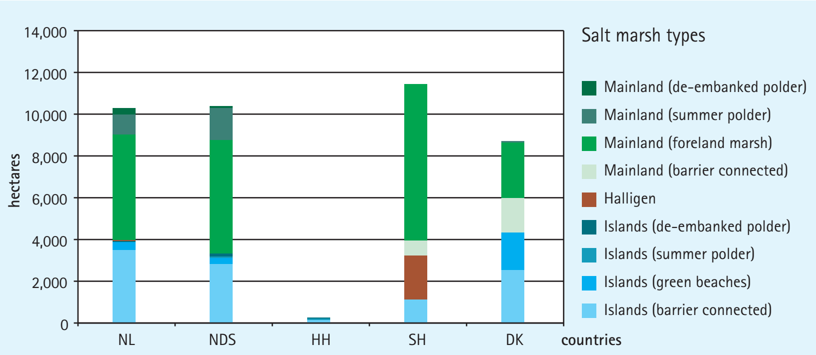

Figure 7.1: Surface area (ha) of the different salt marsh types in the Wadden Sea (see Table 7.1), including pioneer zone except for Niedersachsen and Denmark (border between the pioneer zone and bare soil is chosen at 5% coverage respectively 10% in SH).

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 Head-zone	type	Vegetation typology	Habitats Directive 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*	Pionier 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	

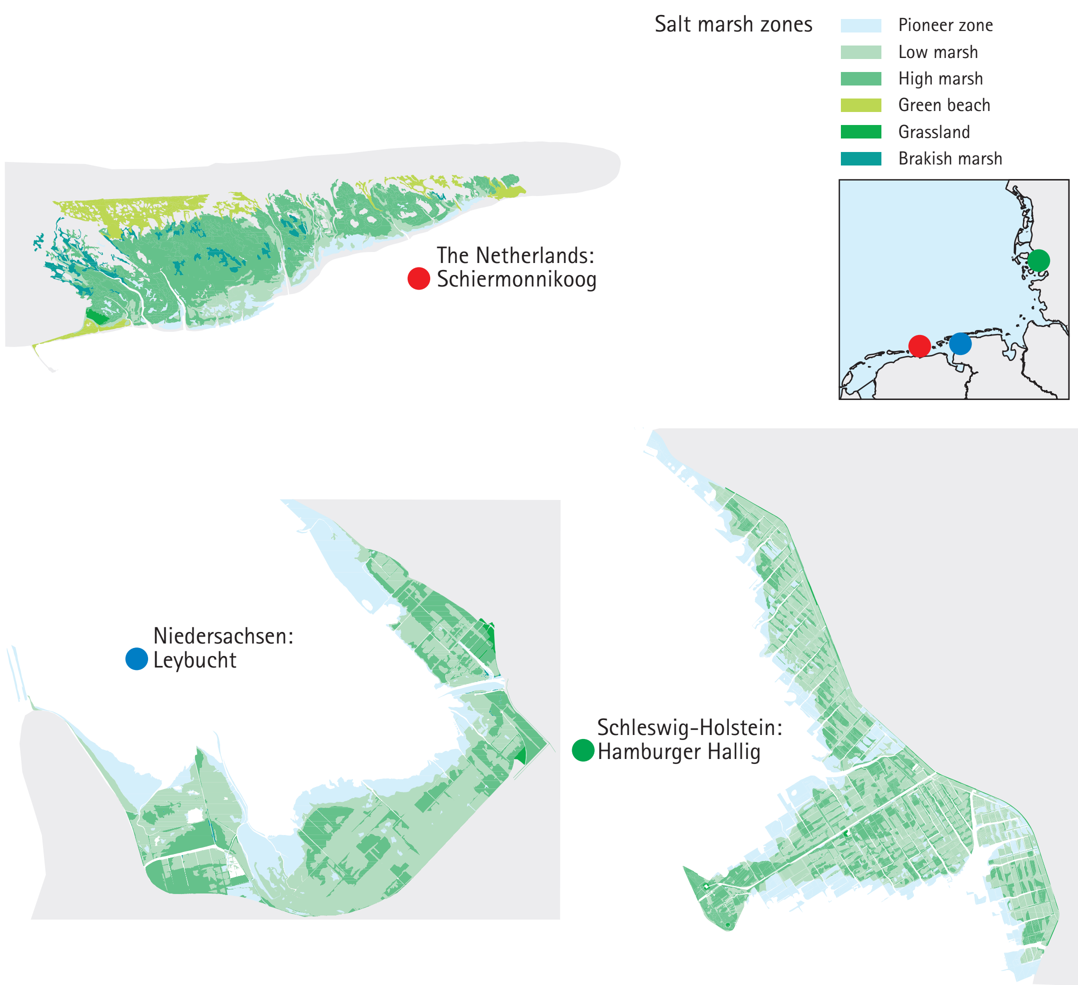

Figure 7.2: TMAP salt marsh zones. Examples from different locations in the Wadden Sea (source: TMAP Data Unit).

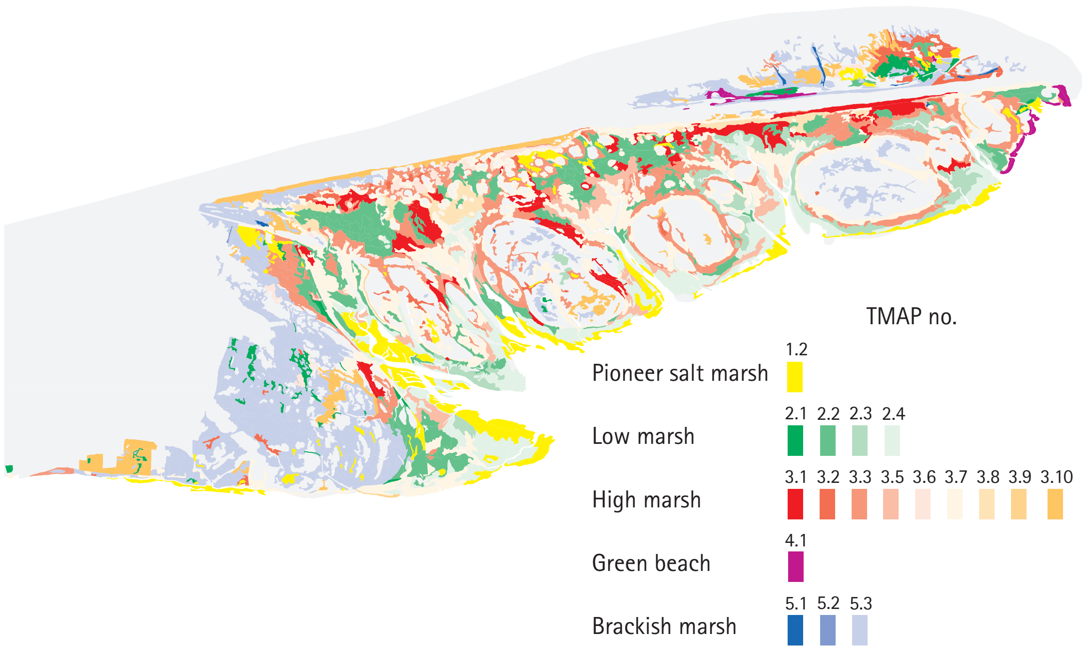

Figure 7.3: TMAP salt marsh vegetation types. Detailed map of the marshes on the island of Terschelling, The Netherlands (source: TMAP Data Unit).

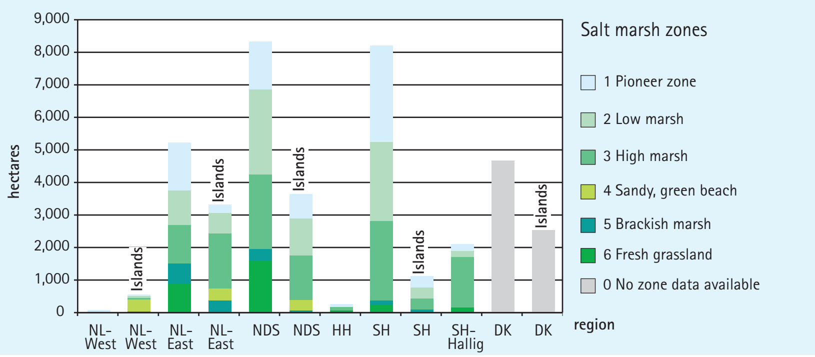

Figure 7.4: Distribution of mainland (left bar) and island (right bar) salt marsh zones (ha) in The Netherlands (NL) (east and west of Terschelling watershed), Niedersachsen (NDS), Hamburg (HH), Schleswig-Holstein (SH) (islands and Halligen separately), no data available from Denmark (DK). Data source: 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.

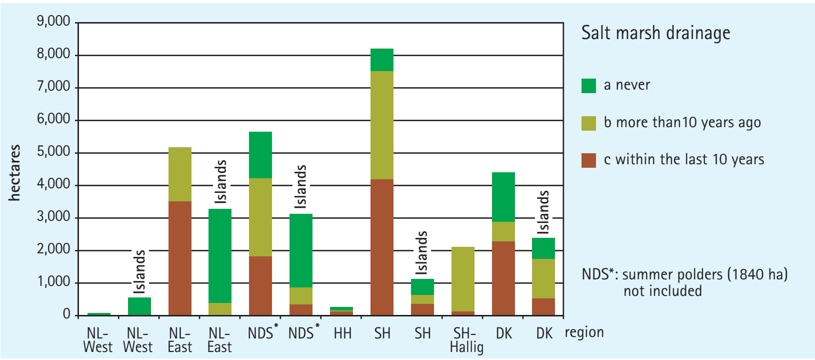

Figure 7.5: Salt marsh areas (ha) with different types of drainage (2002), differentiated for mainland (left bar) and islands (right bar). a: no artificial drainage at all; b: no artificial drainage on a regular basis in the past ten years, c: artificial drainage measures have been carried out during 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

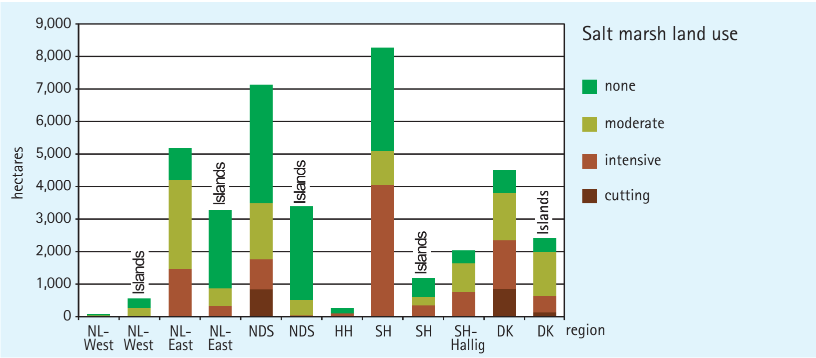

Figure 7.6: Distribution of land use by livestock grazing (none, moderate, intensive) and cutting (in ha) in the Wadden Sea salt marshes on the mainland coast (left bars) and the islands (right bars) (data of the period 2001/2002); pioneer zone in Niedersachsen not included). Data source: TMAP Data Unit,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

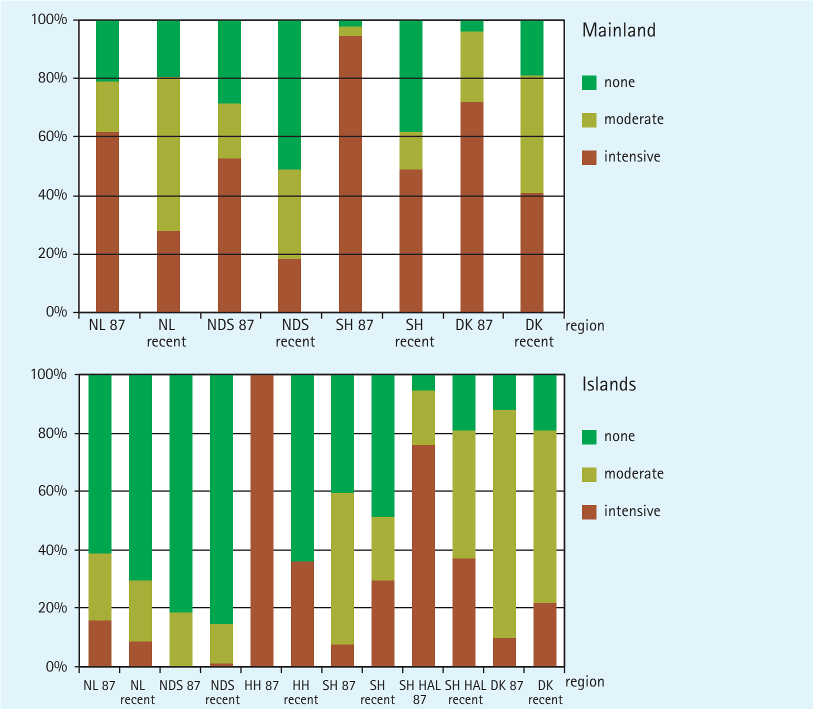

Figure 7.7: Development of land use by livestock grazing in the Wadden Sea salt marshes (mainland and islands), comparison between data from the 1980s and recent data (period 1999/2002). (Sources 1987: Kempf *et al.,* 1987; recent data from TMAP Data Unit). none = overall tall canopy; moderate = diverse 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 intensively 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 Drainage	 Erosion protection Sediment trapping	Land use / management	Examples
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 re-vitalized creeks	b) groynes		Wurster Küste, Buscher Heller, NDS; Noard Fryslân Bûtendyks, 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 studied 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 Rottumerplaat 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, Peasemerlannen) (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 relative 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 2004	Biotope and land use types
Schleswig-Holstein	1988 [2], 1996 [2], 2001/2002	Vegetation and land use types
Denmark	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

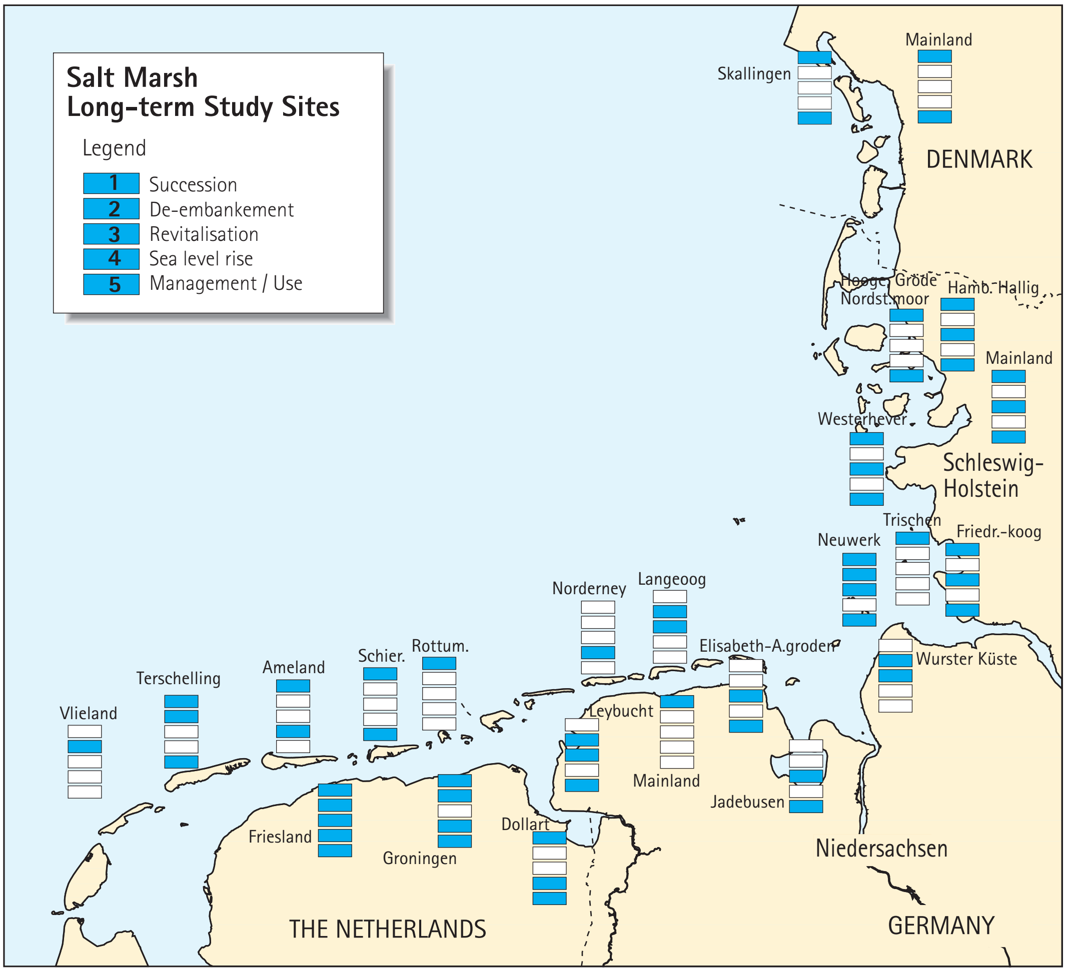

Figure 7.8: Overview of long-term study sites in the Wadden Sea salt marshes. 1 = Succession: Monitoring of sedimentation/erosion (tables, bars, leveling), permanent plots). 2 = De-embankment projects and studies. 3 = Revitalization: reduction of drainage, creek damming experiments, clay pits. 4 = Sealevel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

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) (www.ilternet.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 recommend 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 logging 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 Beukema *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 m^2 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 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.

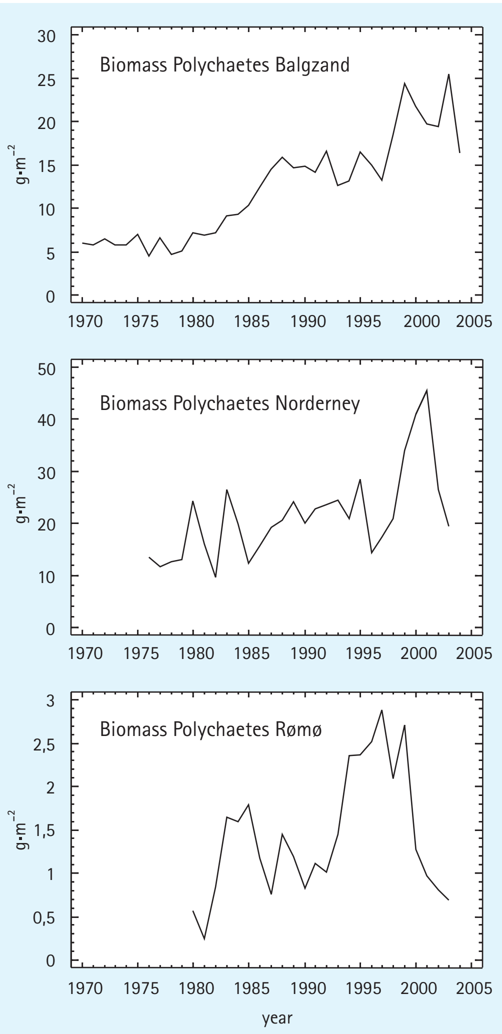

Figure 8.2.1: Development of annual mean biomass (gram ash-free dry weight m^{-2}) of polychaetous worms at intertidal flats in different parts of the Wadden Sea. Note: Danish data (Rømø) refers to 4 species only, *viz.* *Arenicola marina*, *Heteromastus filiformis*, *Nereis diversicolor* and *Scoloplos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

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 (Niedersachen, 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 lamarcki)* 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 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.

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

***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

Jaap de Vlas
Bert Brinkman
Christian Buschbaum
Norbert Dankers
Marc Herlyn
Per Sand Kristensen
Gerald Millat
Georg Nehls
Maarten Ruth
Josien Steenbergen
Achim Wehrman

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:

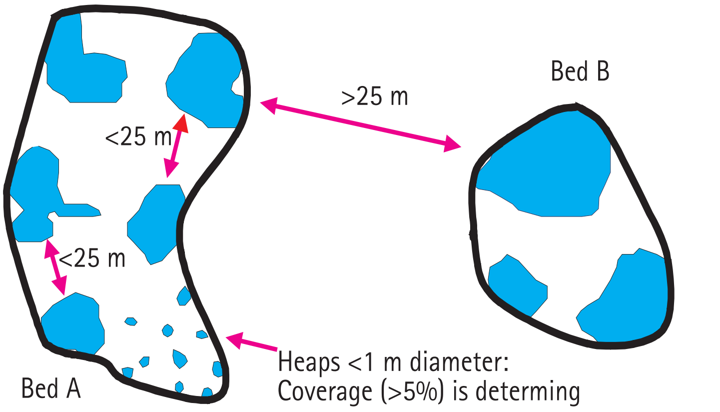
'A mussel bed is a benthic community structured by blue mussels. It may consist of a spatially well-defined irregular collection of more or less protruding smaller beds, which may be called patches, separated by open spaces. This description also includes young beds with a high abundance of small mussels. 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 judgement. 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).



- The patches of blue mussels on the left constitute bed A, and the blue mussel patches on the right constitute bed B. They are considered as two separate beds because they are more than 25 m apart;
- The ten small heaps of less than 1 m diameter belong to bed A because they are nearer by less than 25 m and because their areal coverage is more than 5%;
- The standardized surface area of beds A and B is indicated by the enveloping lines;
- The total coverage of a blue mussel bed is calculated as: % coverage = (sum of patch surfaces / surface of bed envelope) x 100.

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.

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).

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

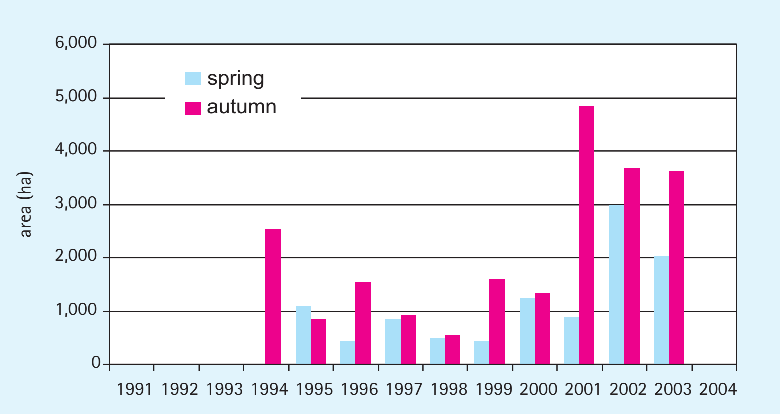


Figure 8.3.2: Surface area (ha) of intertidal mussel beds in the Dutch Wadden Sea since 1994. Data is achieved during a ground survey and reconstructed afterwards (Steenbergen *et al.*, 2003b). An update of the reconstruction was made in November 2004, and thus the data shown can be slightly different 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

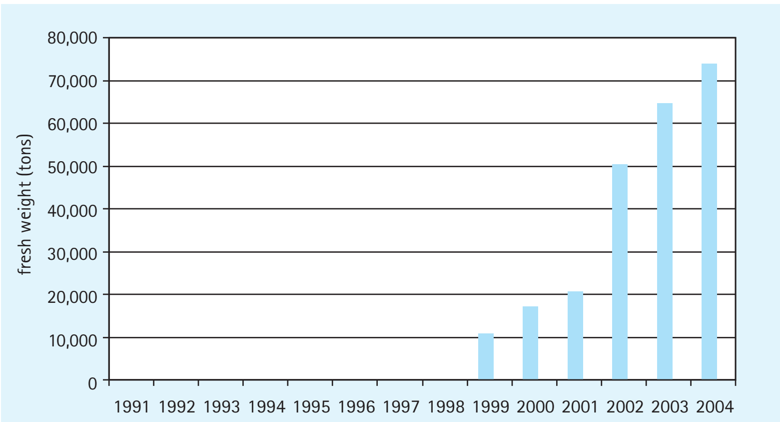


Figure 8.3.3: Total biomass (t fresh weight in spring) of intertidal blue mussels in the Dutch Wadden Sea since 1999 (from: Steenbergen *et al.*, 2004).

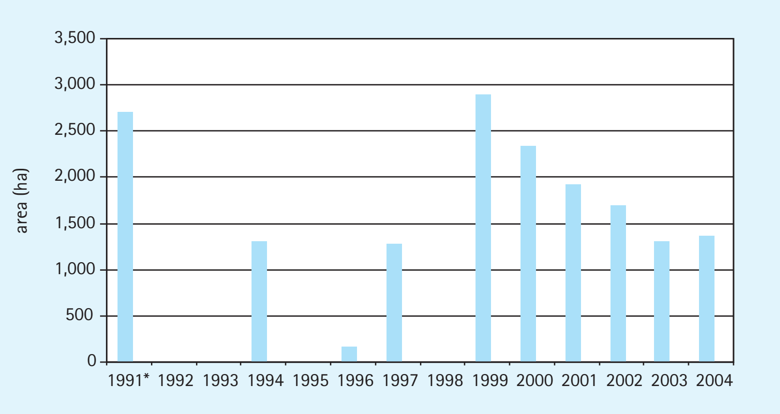


Figure 8.3.4: Development of the total surface area of intertidal blue mussel beds (ha) in Niedersachsen based on yearly spring surveys. (*1991: refers to the period of 1989-91) (from: Herlyn and Millat, 2004).

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

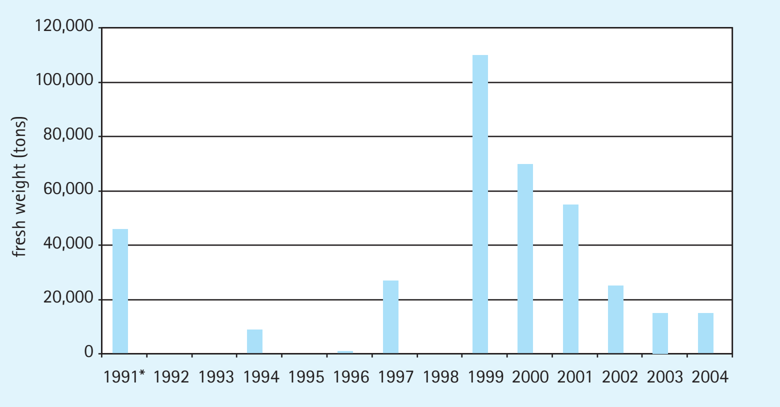


Figure 8.3.5: Development of total biomass (t fresh weight) of intertidal blue mussel beds in Niedersachsen based on spring surveys (from: Herlyn and Millat, 2004).

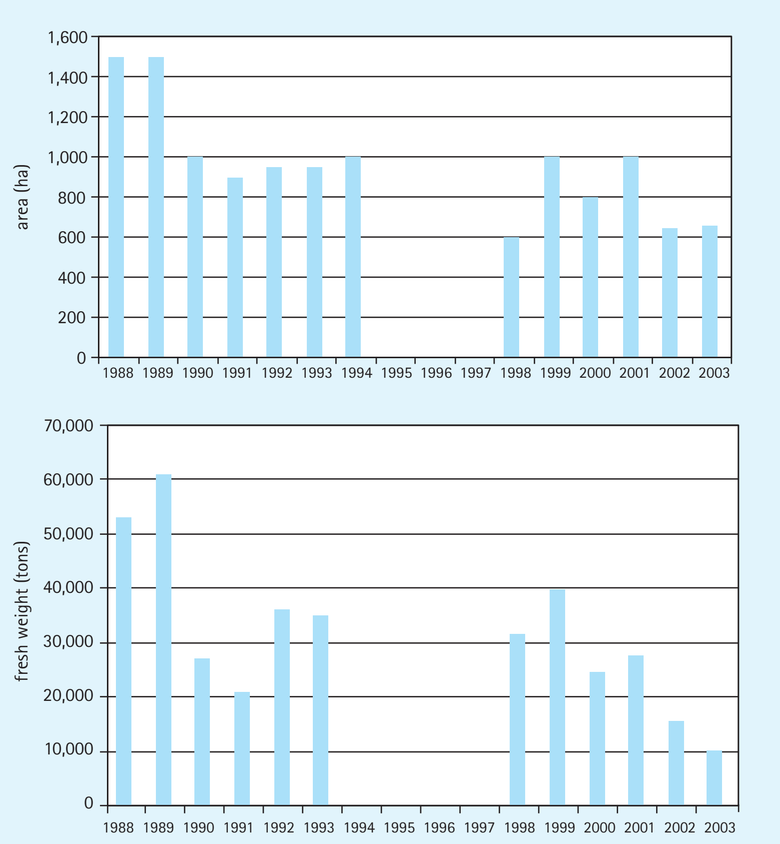


Figure 8.3.6: Development of total surface area (ha) and mussel biomass (t fresh weight) of intertidal blue mussel beds in the Schleswig-Holstein Wadden Sea based on yearly surveys (spring/summer) (from: Nehls and Ruth, 2004).

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.

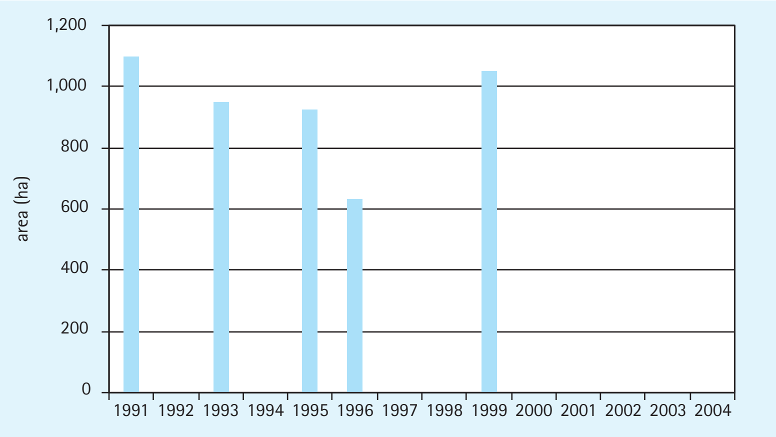
Biomass estimates from before the intensive fisheries of the mid 1980s are not available. After the good spatfall of 1987, 60,000 t (wet weight of the living animal, including shell and enclosed sea water) were present in 1988 and 1989. This decreased to 35,000 t in the early 1990s due to fisheries on 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).

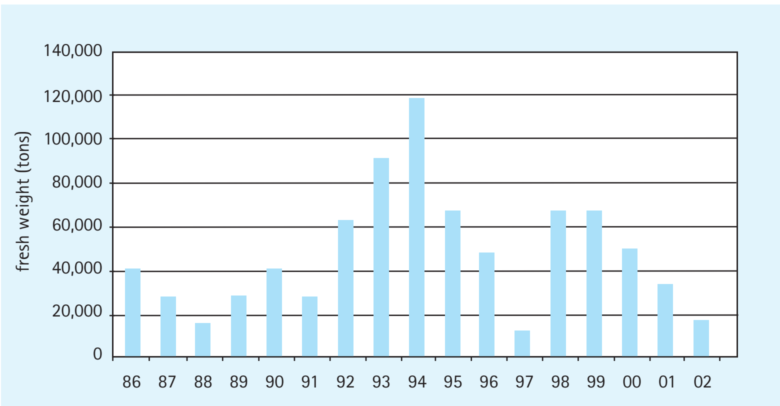
Most of the intertidal mussel beds in the Danish Wadden Sea are very old (>20 years). Some of the intertidal beds are highly dynamic, while others are not. The oldest and most stable beds are in the southern part of Jordsand, in Ho Bight at Sæding Strand and east and west of the isle of Langli. In a 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

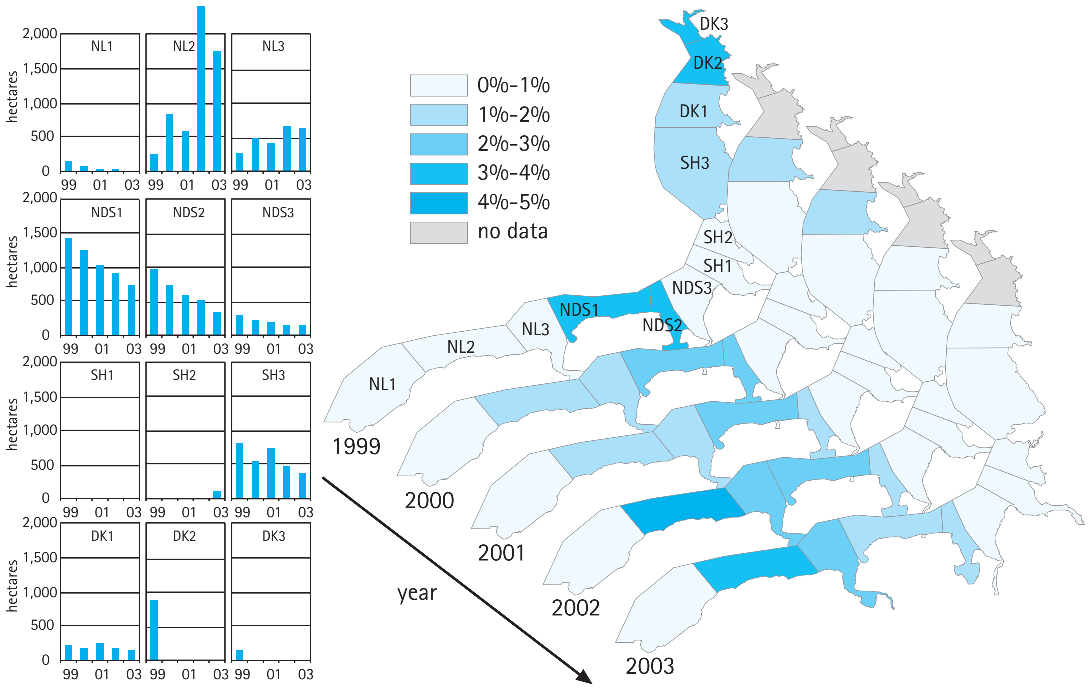


Figure 8.3.9: Distribution of intertidal blue mussel beds in the Wadden Sea in the period 1999-2003. Shown is the development of the surface area of mussel beds (ha) and the area of intertidal flats coverd by mussel beds (%) (calculation based on GIS data, source TMAP data unit).

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.

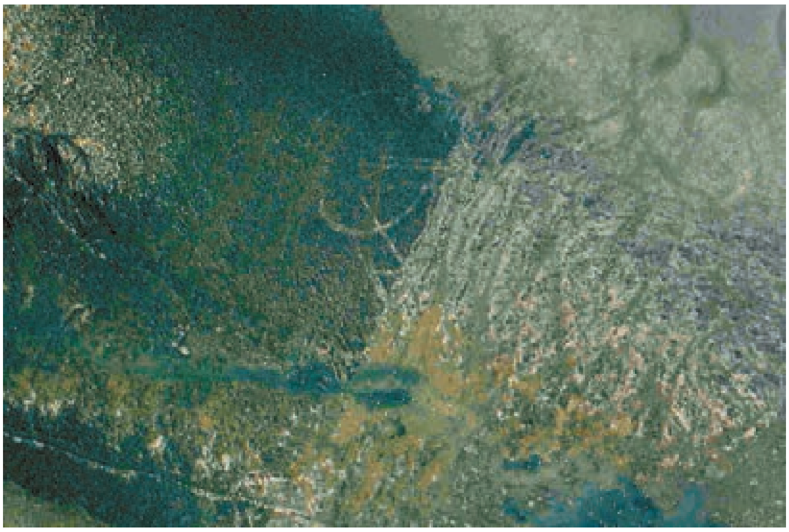
By the end of 2004, a new management plan for mussel fishery in Niedersachsen was adopted which allows continuation of the seed mussel fishery in the intertidal area.

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)



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

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 (Thieltges *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 (Thieltges, 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).

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

Karsten Reise
Zwanette Jager
Dick de Jong
Marieke van Katwijk
Anja Schanz

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

8.4.1 Introduction

Seagrasses occur in shallow waters of almost all coasts. In the Wadden Sea these submersed 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

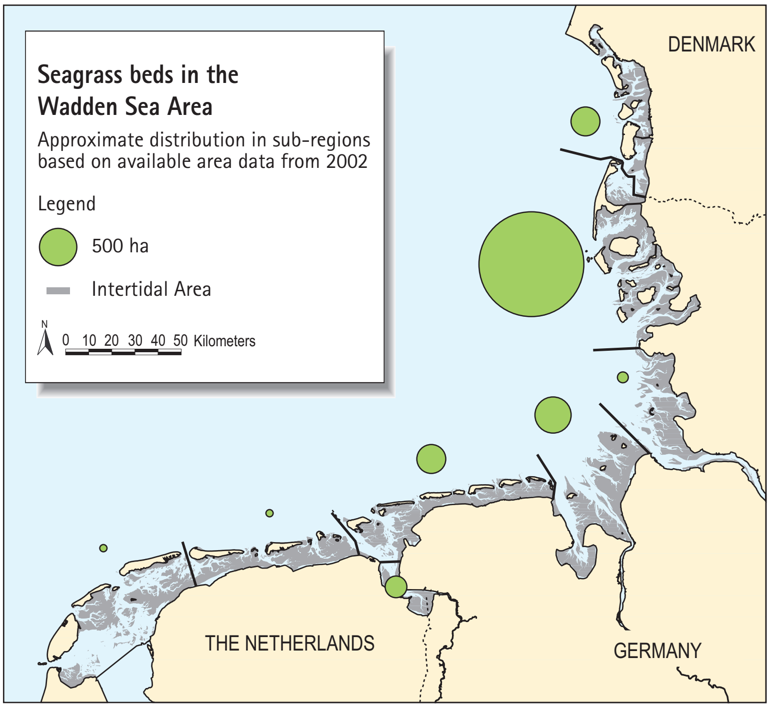

Figure 8.4.1: Distribution of intertidal seagrass beds in the Wadden Sea (in ha) in different sub-regions in 2002.

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, Rottumeroog 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	*Zostera* sp.	Main locations
1935-1937	530	*noltii*	Bockhorner-Sander, Vareler, Seefelder and Stollhammer Watt
1975-1977	280	*marina+noltii*	Vareler Watt
1993	350	*noltii+marina*	Seefelder Watt
2000-2002	580	*noltii*	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 hs 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*.

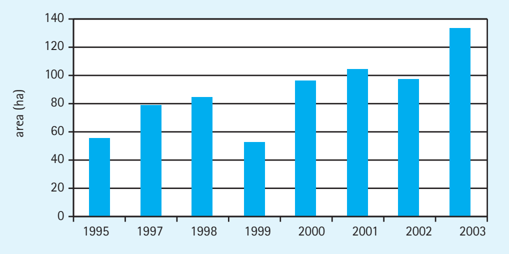

Figure 8.4.2: Tidal flat area with seagrass (ha) in the Dutch Wadden Sea compiled from direct observation at ground level between 1995 and 2003 (Dutch monitoring program, MWTL; see also www.zeegras.nl).

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 northen Lister Dyb and in the Juvre Dyb tidal area revealed 430 ha of seagrass beds (Amternes Vadehavssamarbejde, 2004).

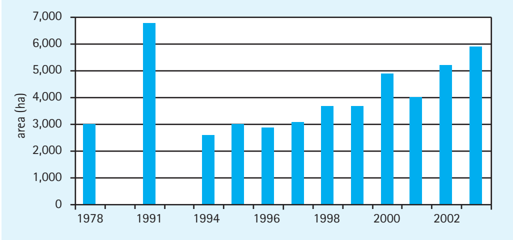

Figure 8.4.3: Tidal flat area with seagrass beds (ha) in the North Frisian Wadden Sea between Eiderstedt and Sylt, compiled from aerial surveys conducted in August or September between 1978 and 2003.

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.zeegras.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.

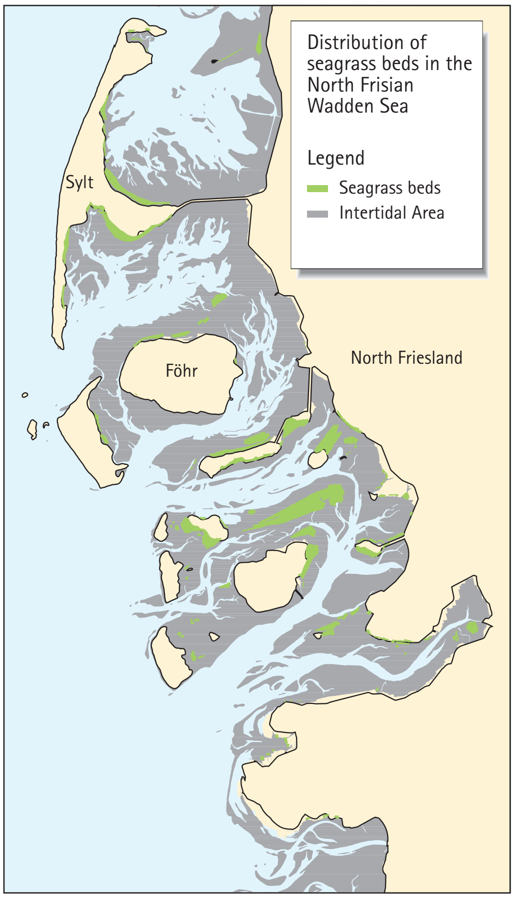

Figure 8.4.4: Distribution of intertidal seagrass in the North Frisian Wadden Sea in 2002 (NPA Tönning).

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 submersed 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 covariables 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. 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 Hermus, 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 leafs. 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 dikeline 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 transplantations 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 reintroduce 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 development 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-sluices 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.

Target

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

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 m^2. These reef fragments were uninhab-

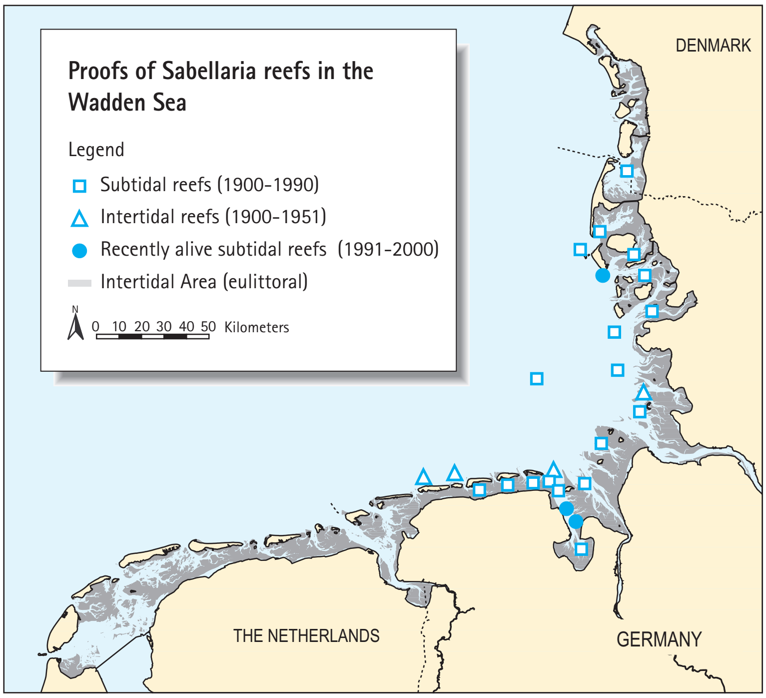

Figure 8.5.1: Proofs of *Sabellaria* reefs in the Wadden Sea

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 (Pawlik, 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 (Ssymank 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

Jaap de Vlas
Bert Brinkman
Christian Buschbaum
Norbert Dankers
Marc Herlyn
Per Sand Kristensen
Gerald Millat
Georg Nehls
Maarten Ruth
Josien Steenbergen
Achim Wehrman

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 periwin-

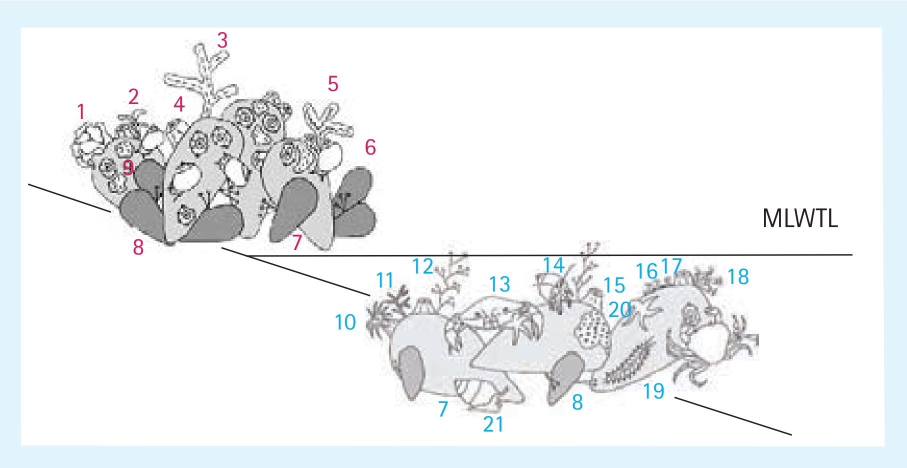


Figure 8.5.2: Subtidal (below) and intertidal (above) mussel beds show different ecological patterns in relation to biogenic structure, species interactions and the community of associated organisms. Typical species associated with intertidal and subtidal mussel beds are shown. MLWTL = Mean Low Water Tide Level.

1 *Chondrus crispus* (Rhodophyta); 2 *Enteromorpha spec.* (Chlorophyta); 3 *Fucus vesiculosus* forma *mytili* (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 *Alcyonidium mytili* (Bryozoa); 21 *Buccinum undatum* (Gastropoda), (after Buschbaum and Saier, 2003).

kles (*L. littorea*) are abundant in intertidal mussels 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, molluscs, 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).

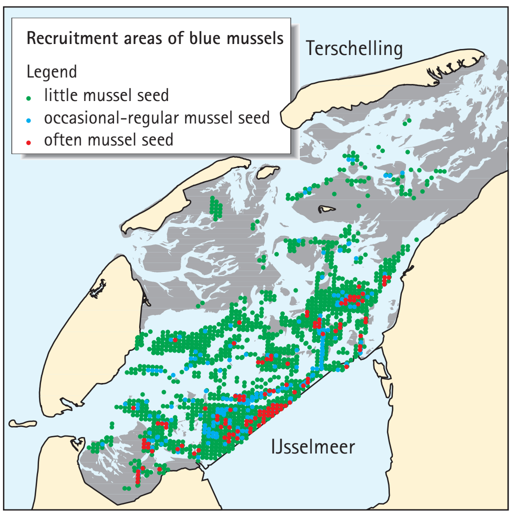


Figure 8.5.3: Recruitment areas of blue mussels (*Mytilus edulis*) in the western Dutch Wadden Sea. Average based on surveys in spring 1992-2004 (source: RIVO-CSO, Yerseke).

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 interspaced 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-

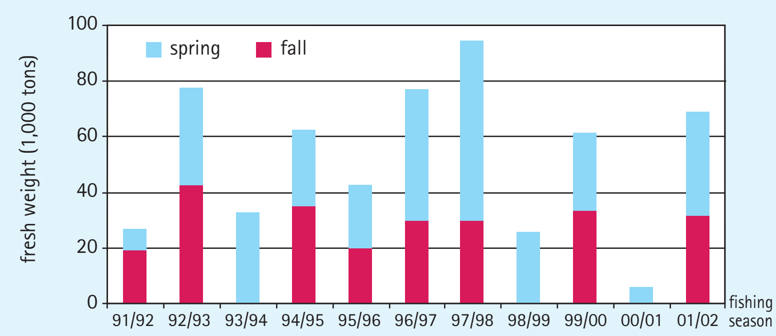


Figure 8.5.4: Gross mussel seed capture in the subtidal western Dutch Wadden Sea per season (Kamermans *et al.*, 2003).

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-

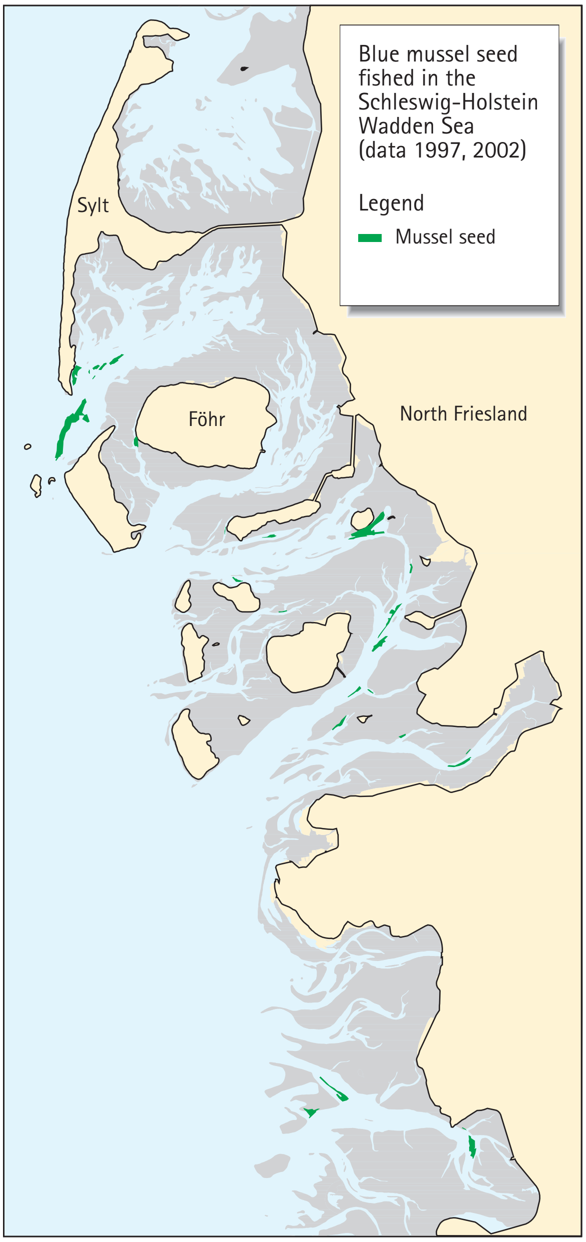


Figure 8.5.5: Locations in Schleswig-Holstein (green) where mussel seed was fished in 1997 and 2002, indicating the most important areas with subtidal mussel beds. Data taken from fishing activity monitored by a blackbox

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 kg/m²), 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.

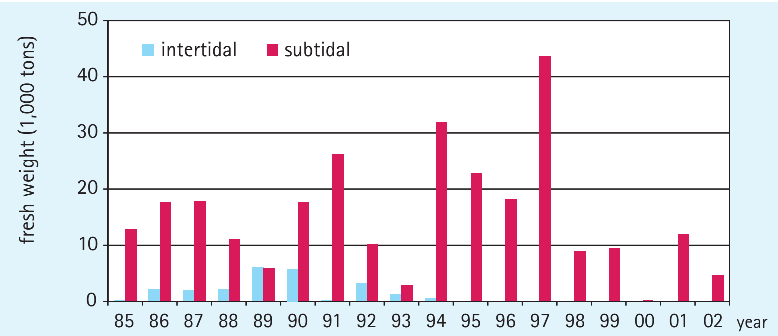
Mussel fishery

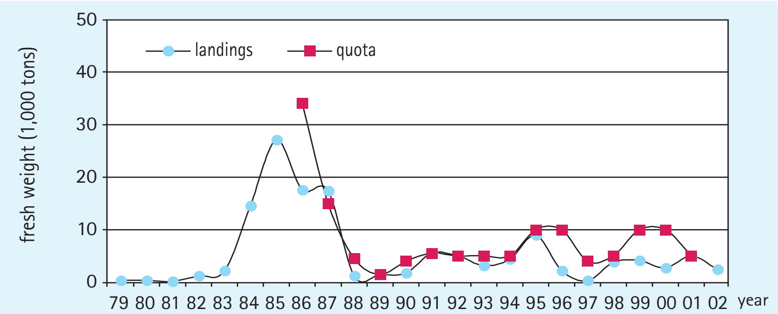
The amount of seed mussels taken by the mussel fishery in Schleswig-Holstein is shown in Figure 8.5.6. In Schleswig-Holstein, mussel seed fishing of new spatfall starts as early as possible, normally in July or early August at a mean mussel length of about 5 mm. Seed fishing is continued until late October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

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).





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.

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'.

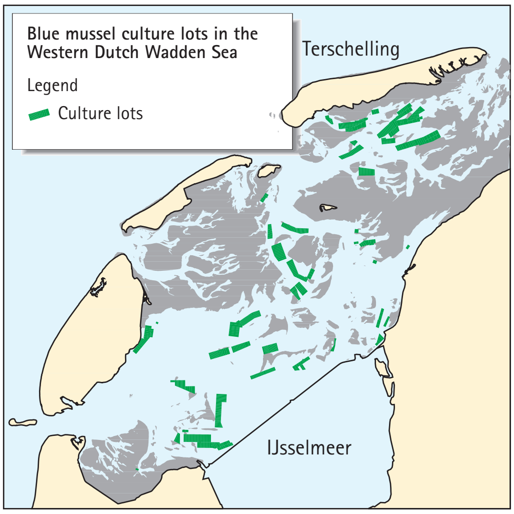


Figure 8.5.8: Culture lots in the Dutch Wadden Sea (source: RIVO).

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-

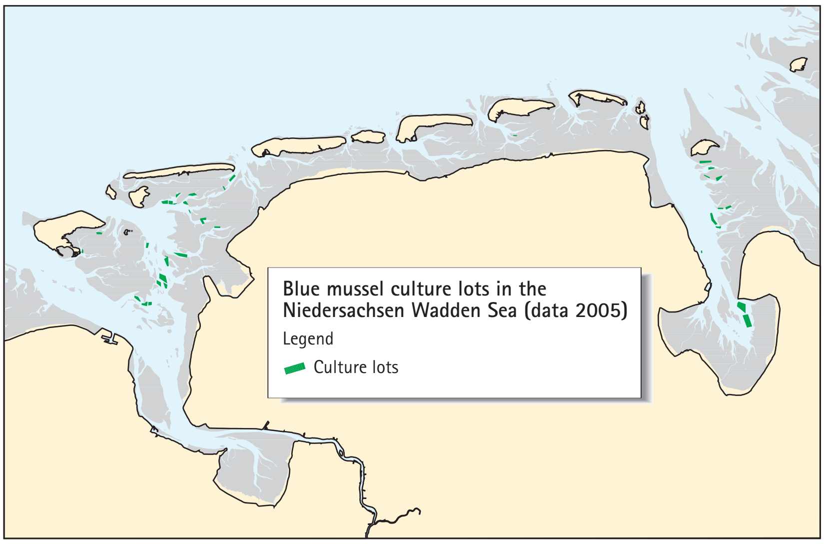


Figure 8.5.9: Location of mussel culture lots in Niedersachsen (source: Nationalparkverwaltung Niedersächsisches Wattenmeer).

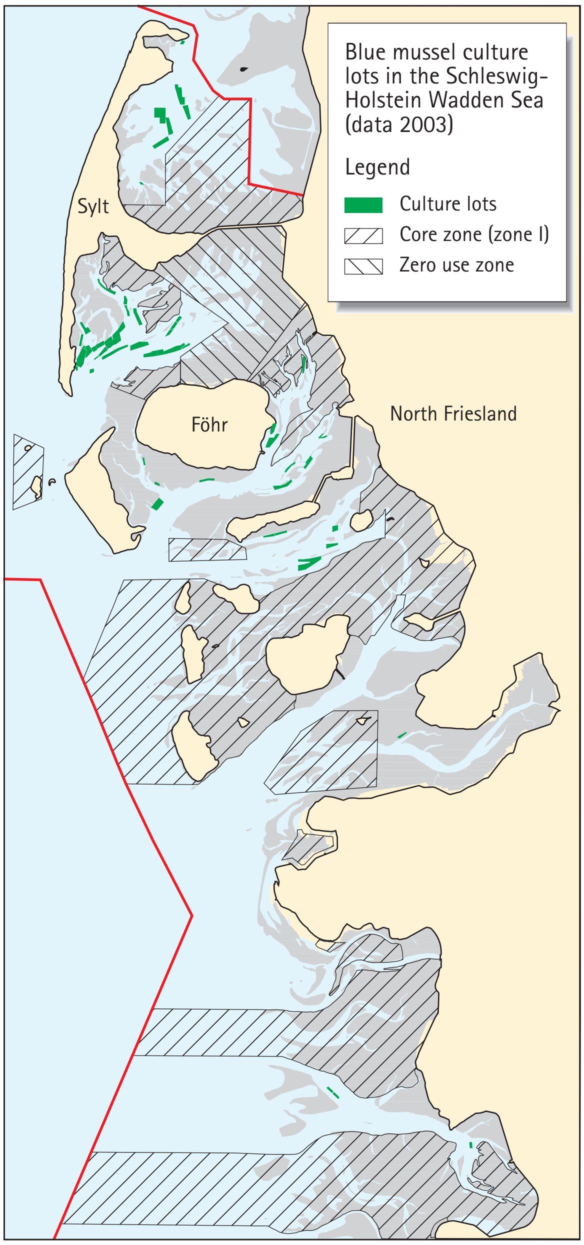


Fig 8.5.10: Mussel culture lots in the Wadden Sea of Schleswig-Holstein in 2003, (Nehls and Ruth, 2004).

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 (total: 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 (relaying, 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	*Clupea harengus*	marine juvenile	pelagic		-	MB
Sprat	*Sprattus sprattus*	marine juvenile	pelagic		-	MB
Anchovy	*Engraulis encrasicolus*	marine seasonal	pelagic		-	MB
Smelt	*Osmerus eperlanus*	diadromous	pelagic		-	MB & MFS
Twaite shad	*Alosa fallax*	diadromous	pelagic	Annex II, V	vulnerable	MB & MFS
Houting	*Coregonus oxyrinchus*	diadromous	pelagic	Annex II, IV	critical	MPS
Salmon	*Salmo salar*	diadromous	pelagic	Annex II, V, [4]	critical	MPS
Sea trout	*Salmo trutta*	diadromous	pelagic		endangered	MPS
Eelpout	*Zoarces viviparus*	resident	demersal		-	DFS, DYFS
Bull rout	*Myoxocephalus scorpius*	resident	demersal		-	DFS, DYFS
Five-bearded rockling	*Ciliata mustela*	resident	demersal		-	DFS, DYFS
Hooknose	*Agonus cataphractus*	resident	demersal		-	DFS, DYFS
Butterfish	*Pholis gunellus*	resident	demersal			DYFS
Sand goby	*Pomatoschistus minutus*	near-resident	demersal			DYFS
Plaice	*Pleuronectes platessa*	marine juvenile	demersal		-	DFS, DYFS
Sole	*Solea solea/vulgaris*	marine juvenile	demersal		-	DFS,DYFS
Dab	*Limanda limanda*	marine juvenile	demersal		-	DFS, DYFS
Flounder	*Platichthys flesus*	diadrom/resident	demersal		-	DFS, DYFS, MFS
Cod	*Gadus morhua*	marine juvenile	demersal			DYFS
Whiting	*Merlangius merlangus*	marine juvenile	demersal			DYFS
Eel	*Anguilla anguilla*	diadromous	demersal		-	DFS, DYFS, MFS
River Lamprey	*Lampetra fluviatilis*	diadromous	demersal	Annex II, V	endangered	MB & MFS
Three-spined stickleback	*Gasterosteus aculeatus*	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 m²) 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 subregion. 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 management 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).

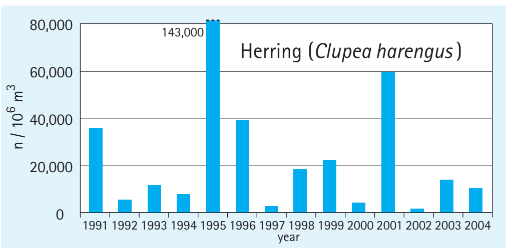


Figure 8.6.1: Abundance of herring (*Clupea harengus*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

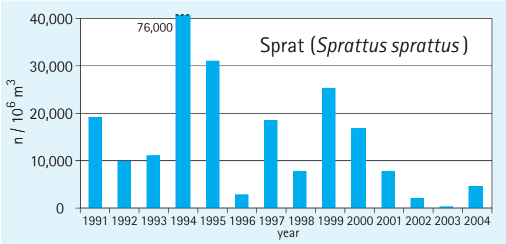


Figure 8.6.2: Abundance of sprat (*Sprattus sprattus*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

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.

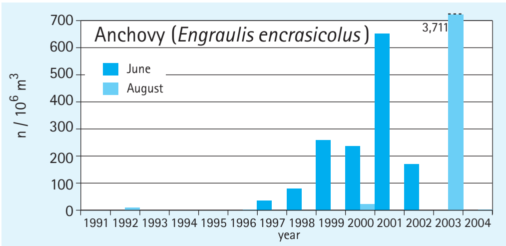


Figure 8.6.3: Increasing abundance of anchovies (*Engraulis encrasicolus*) during fish monitoring in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches per year.

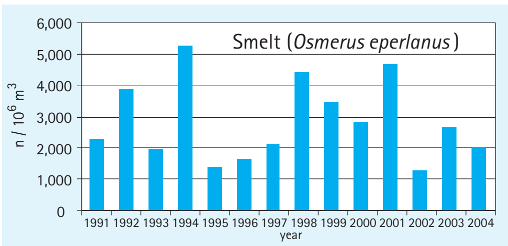


Figure 8.6.4: Abundance of smelt (*Osmerus eperlanus*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

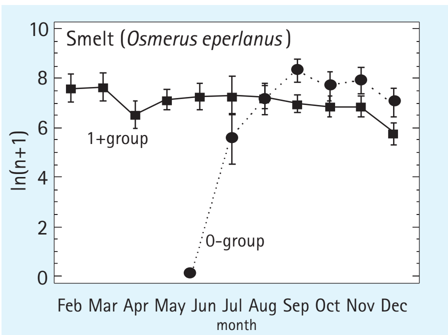


Figure 8.6.5: Catch of smelt (*Osmerus eperlanus*) (ln of the number standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999-2001; bars indicate 95% confidence interval.

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.).

Twaite shad (Photo: Z. Jager)

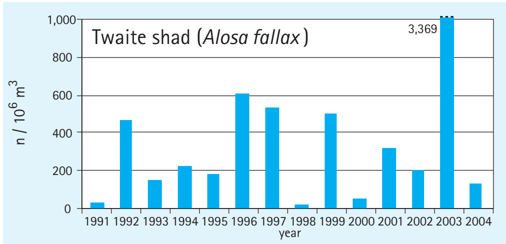


Figure 8.6.6: Abundance of twaite shad (*Alosa fallax*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

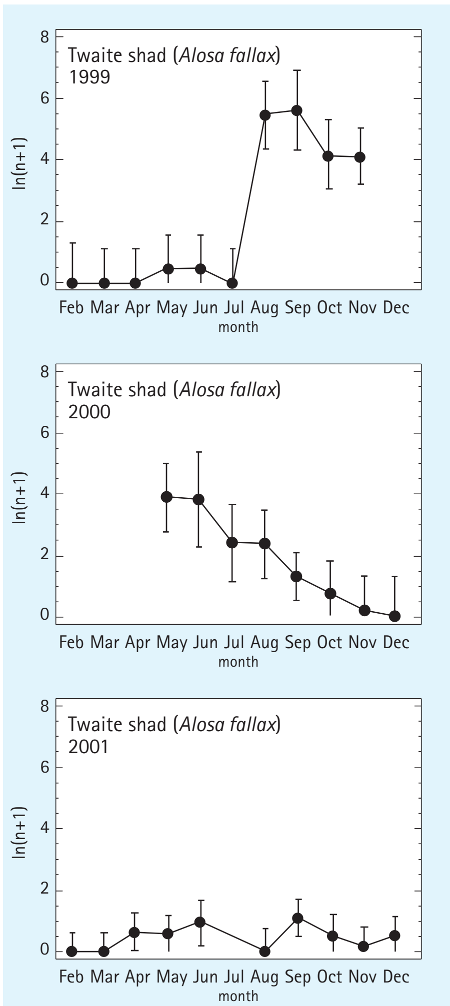


Figure 8.6.7: Catch density of twaite shad (*Alosa fallax*) (ln of the number standardized per 100 m² of net opening per tide) in the Ems-Dollard during 1999-2001; bars indicate 95% confidence interval.

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.

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 possibility 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 (ovoviviparous), 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-

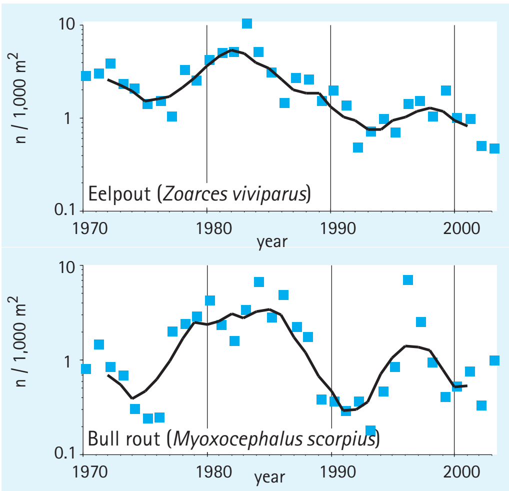


Figure 8.6.8: Catch rates of eelpout (*Zoarces viviparus*) (a) and bull rout (*Myoxocephalus scorpius*) (b) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).

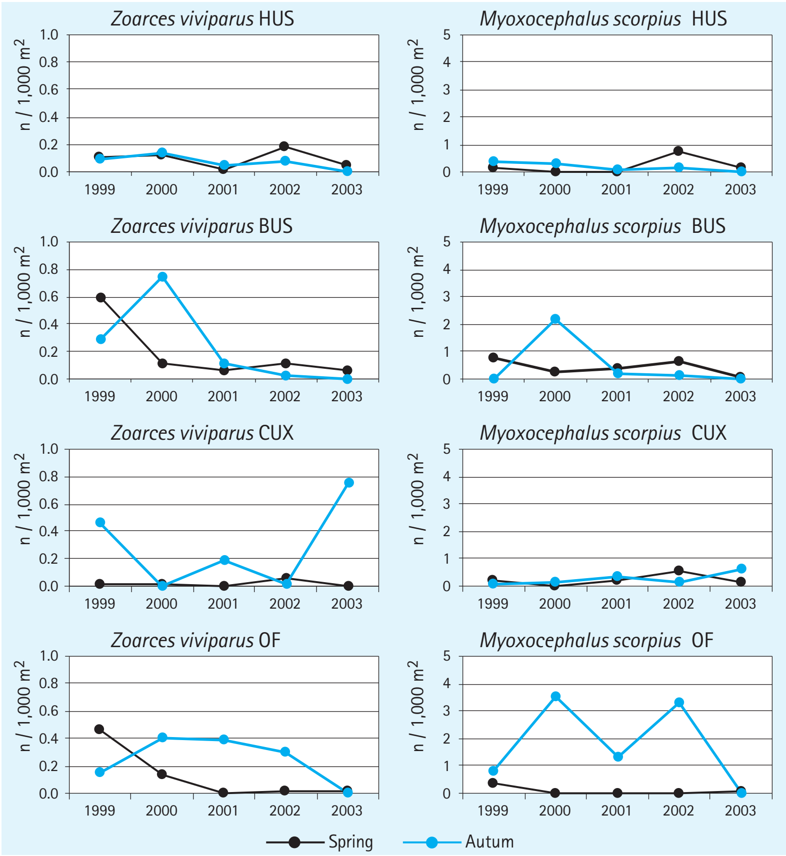


Figure 8.6.9: Catch rates of eelpout (*Zoarces viviparus*) (left) and bull rout (*Myoxocephalus scorpius*) (right) in the DYFS for the years 1999 to 2003 for the four German Wadden Sea regions: HUS = west and north of Husum, BUS = west of Büsum, CUX = near Cuxhaven, Elbe estuary, OF = East Frisia north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

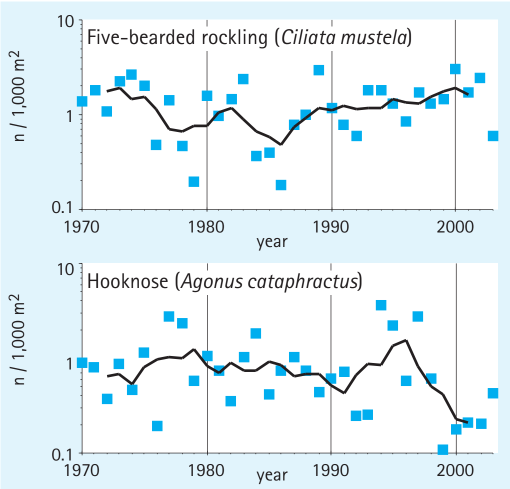


Figure 8.6.10: Catch rates of five-bearded rockling *(Ciliata mustela)* (a) and hooknose (*Agonus cataphractus*) (b) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).

(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 two 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

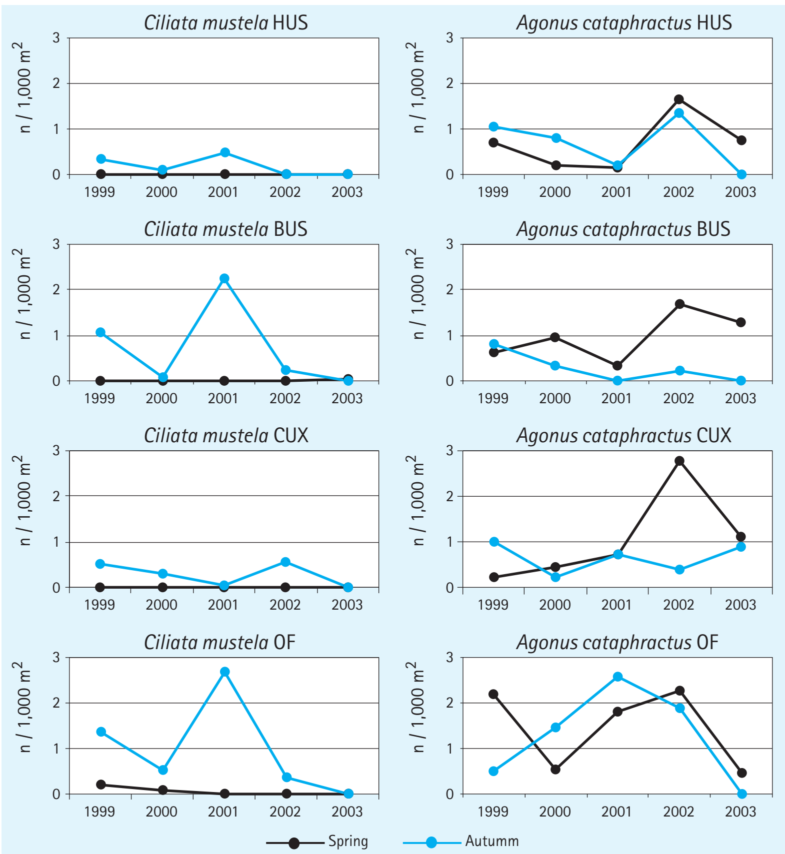


Figure 8.6.11: Catch rates of five-bearded rockling *(Ciliata mustela)* (left) and hooknose (*Agonus cataphractus*) (right) in the DYFS for the years 1999 to 2003 for the four German Wadden Sea regions: HUS = west and north of Husum, BUS = west of Büsum, CUX = near Cuxhaven, Elbe estuary, OF = East Frisia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

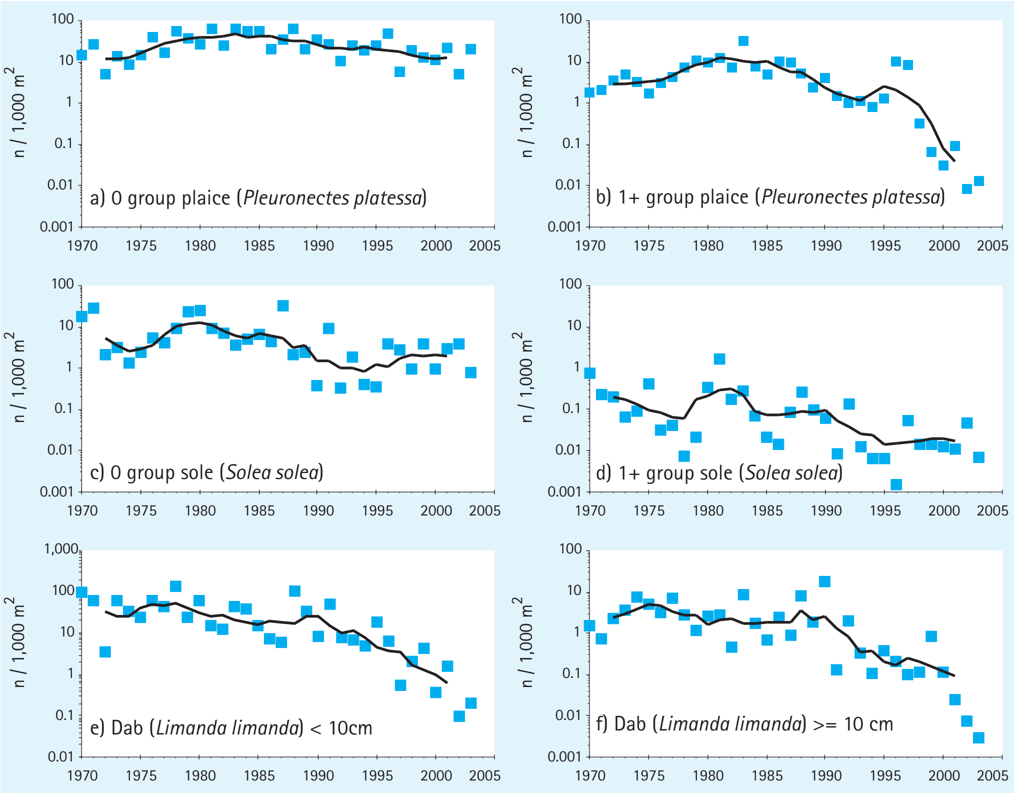


Figure 8.6.12: Catch rates by age group or size class of plaice (*Pleuronectes platessa*) (a-b), sole (*Solea solea*) (c-d) and dab (*Limanda limanda*) (e-f) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).

sand goby occurred in all catches with catch rates up to 30 per 1,000 m^2. 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

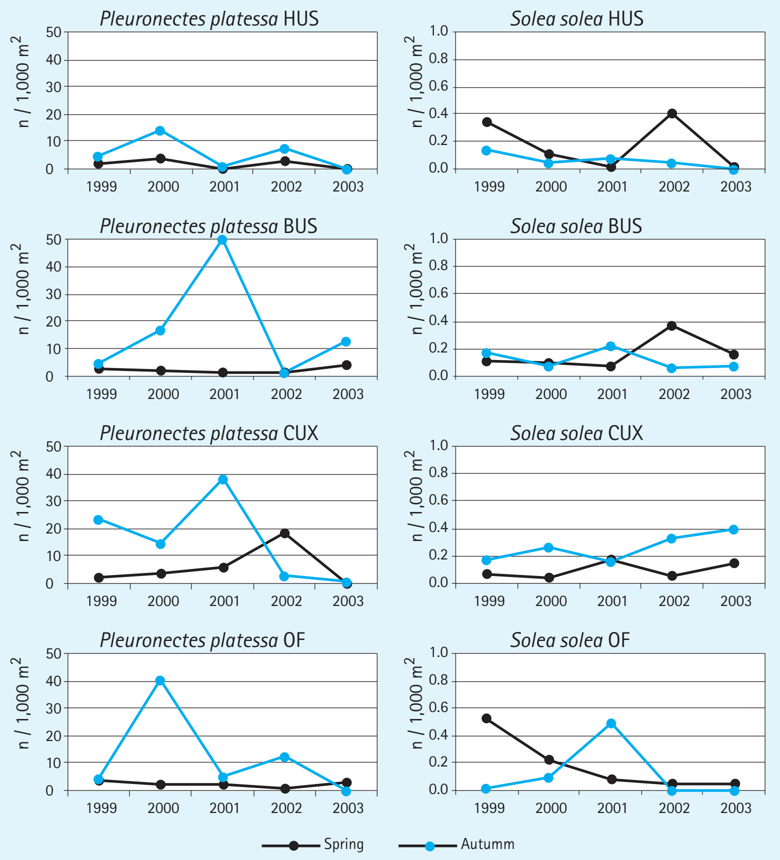
Flatfish

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).

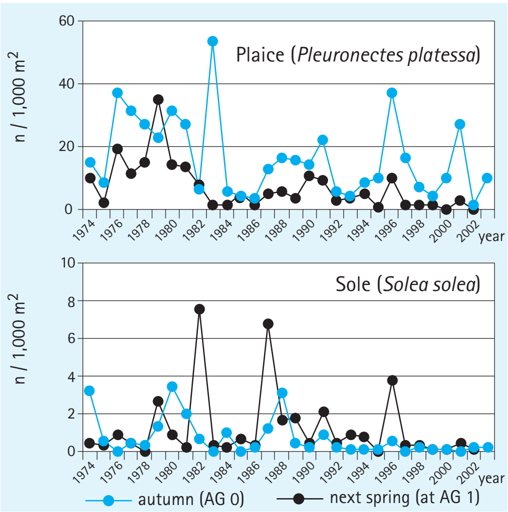
Sole may also show outstanding year classes as in 1982 or 1987 (Figure 8.6.15). This species is less common, with a preference for the deeper parts of the German Wadden Sea. Since the good year class of 1996, densities have remained rather low.

Dab exhibited rather low densities (<5 per 1,000 m^2) in all German regions except for the East Frisian part, where densities of 10-20 per 1,000 m^2 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 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.

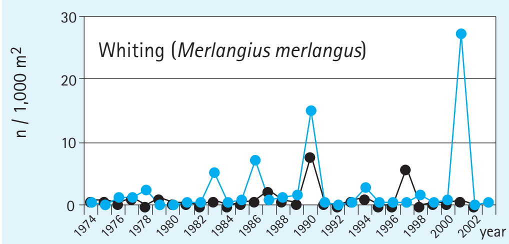


Figure 8.6.16: Catch rates of whiting (*Merlangius merlangus*) in the DYFS for the years 1974 to 2003 for the Schleswig-Holstein region from spring and autumn campaigns (AG = Age Group).

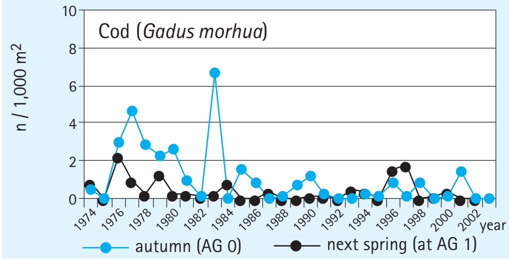


Figure 8.6.17: Catch rates of cod (*Gadus morhua*) in the DYFS for the years 1974 to 2003 for the Schleswig-Holstein region from spring and autumn campaigns (AG = Age Group).

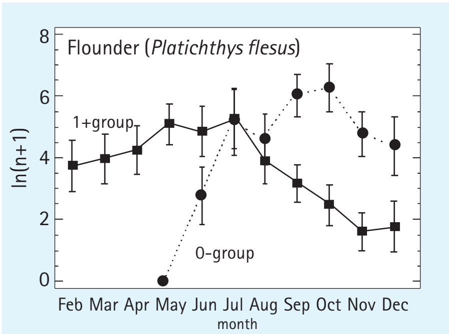


Figure 8.6.18: Catch of flounder (*Platichthys flesus*) (ln of the number standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999-2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

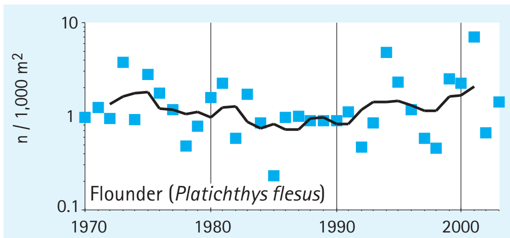


Figure 8.6.19: Catch rates of flounder (*Platichthys flesus*) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).

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.

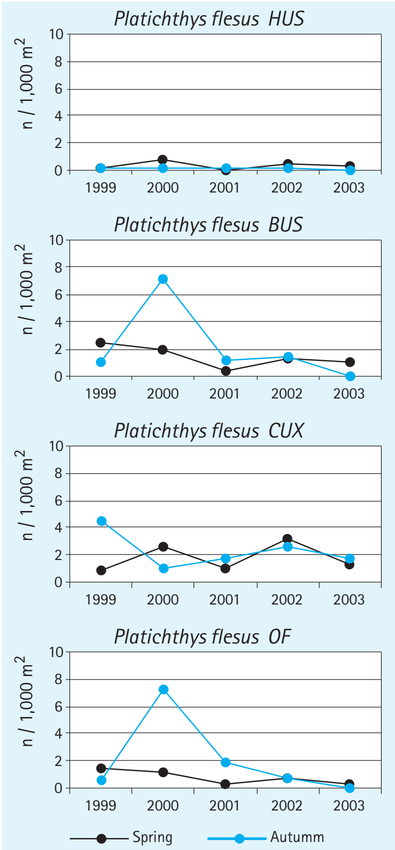


Figure 8.6.21: Catch of eel (*Anguilla anguilla*) (ln of the number standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999-2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

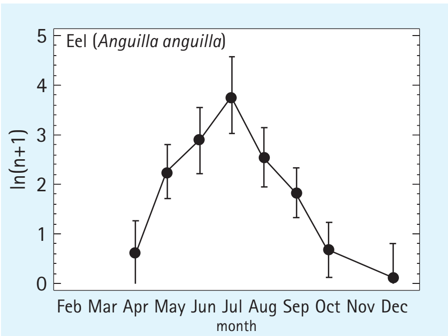
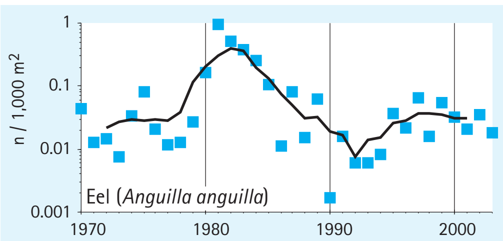


Figure 8.6.22: Catch rates of eel (*Anguilla anguilla*) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).



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 m²) 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 (Wintermans 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-

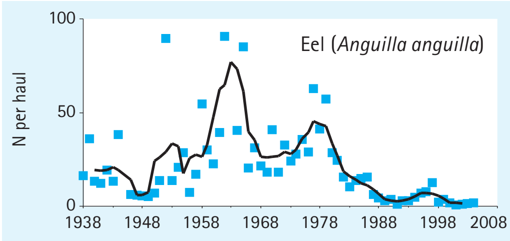


Figure 8.6.23: Catch rates of glass eel (*Anguilla anguilla*) migrating into fresh water at Den Oever (western Dutch Wadden Sea) in April (unpublished data W. Dekker; ICES, 2004b).

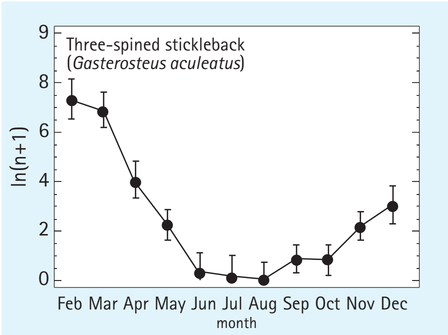


Figure 8.6.24: Catch of three-spined stickleback (*Gasterosteus aculeatus*) (ln of the number standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

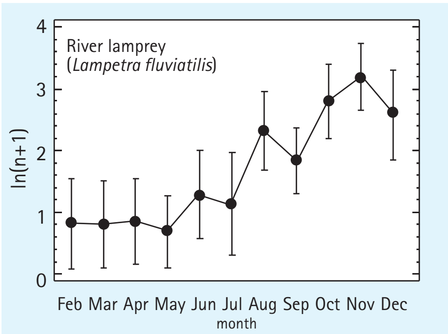


Figure 8.6.25: Catch of river lamprey (*Lampetra fluviatilis*) (ln of the numbers standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

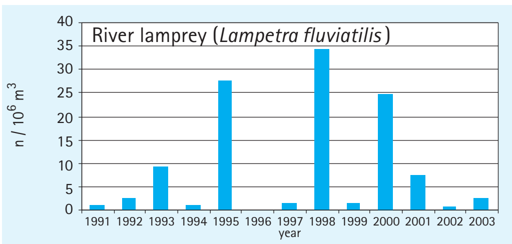


Figure 8.6.26: Abundance of river lamprey (*Lampetra fluviatilis*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

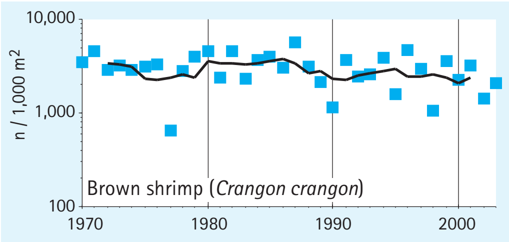


Figure 8.6.27: Catch rates of brown shrimp (*Crangon crangon*) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).

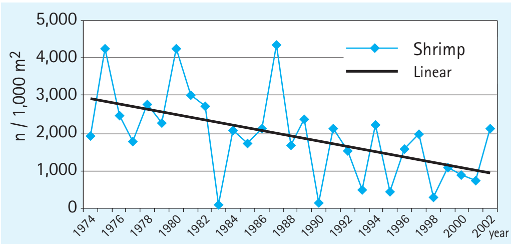


Figure 8.6.28: Catch rates of brown shrimp (*Crangon crangon*) (autumns) in the Schleswig-Holstein region for 1974 to 2002 (DYFS data).

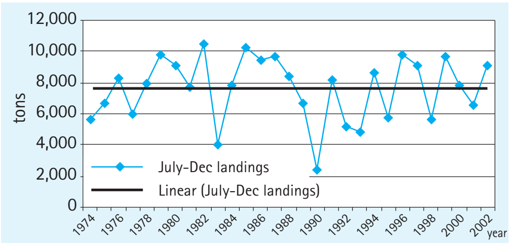


Figure 8.6.29: Semi-annual landings of brown shrimp (*Crangon crangon*) (July to December) in Germany for 1974 to 2002.

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 during 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 coverage 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

Jörg Petersen
Gerard Janssen
Evert Jan Lammerts
Iris Menn
Saskia Mulder

9.1 Beaches

Saskia Mulder
Gerard Janssen
Iris Menn

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 Assessment Program be adapted on the basis of advice by an 'Expert Group Beaches'.

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

9.1.2 Beaches as ecosystems

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

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

9.1.4 Beaches in the Wadden Sea

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

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

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

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

9.1.5 Human activities and impacts on the Targets

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

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

Jörg Petersen
Evert Jan Lammerts

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

9.2.1 Introduction

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

9.2.1.1 Protection and management

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

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

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

Targets

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

9.2.1.2 From the 1999 QSR up till now

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

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

TMAP-type	Dune-types	Vegetation	Natura 2000 habitat types
Xerosere:			
X.0	**Dunes**		
X.1	**Beach plains**	No vegetation	
X.2	**Beach driftline**		
X.2.0	Beach driftline, unspecific		
X.2.1	Cakile maritima type	Cakiletum maritimae	
X.3	**Embryonic dunes**		2110
X.3.0	Embryonic dunes, unspecific		2110
X.3.1	Elymus farctus type	Elymo-Agropyretum, Honkenyo-Agropyretum juncei	2110
X.4	**White dunes**		2120
X.4.0	White dunes, unspecific		2120
X.4.1	Ammophila arenaria type	Elymo-Ammophiletum, Ammocalamagrostis baltica unit	2120
X.5	**Dune grassland**		2130
X.5.0	Dune grassland, unspecific		2130
X.5.1	Corynephorus canescens type (+/- dominant Campylopus introflexus)	Violo-Corynephoretum (+/- Campylopus introflexus), Corynephorion vegetation	2130
X.5.2	Koeleria arenaria type	Tortulo-Phleetum, Phleo-Tortuletum, Festuco-Galietum, Airetum praecocis, Koelerion vegetation	2130
X.5.3	Botrychium lunaria type	Botrychio-Polygaletum, Nardo-Galion vegetation	2130
X.5.4	Carex arenaria type	Carex arenaria unit	2130
X.5.5	Deschampsia flexuosa type	Deschampsia flexuosa unit	2130
X.6	**Dune heath**		mostly 2140
X.6.0	Dune heath, unspecific		mostly 2140
X.6.1	Empetrum nigrum type	Hieracio-Empetretum, Polypodio-Empetretum	2140
X.6.2	Calluna vulgaris type	Hieracio-Empetretum – dom. Calluna vulgaris	2150
X.7	**Dune scrub**		
X.7.0	Dune scrub, unspecific		
X.7.1	Hippophae rhamnoides type	Hippophao-Sambucetum nigrae, Salici arenariae-Hippophaetum	2160
X.7.2	Salix repens agg. type	Dry – fresh Salix repens ssp. argentea (arenaria) and repens ssp. repens vegetation, Pyrolo-Salicetum, Rosa spinosissima-Salix arenaria unit	2170
X.7.3	Rosa canina type	Rhamno-Prunetea vegetation	-
X.7.4	Rosa rugosa type	Rosa rugosa unit	-
X.8	**Dune woodland**		
X.8.0	Dune woodland, unspecific		
X.8.1	Populus tremula type	Populus tremula / Betula pendula / Quercus robur vegetation	2180
X.8.2	Pinus spp. Type	Pinus spp. vegetation	
X.9	**Open dune areas**	No vegetation	mostly 2130
X.10	**Eutrophic dune areas**	Dry vegetation with: Urtica spp., Epilobium angustifolium, etc.	mostly 2130
X.11	**Salty dune areas**	Combination of Xeroserie and Haloserie vegetation	mostly 2130
X.12	**Wandering dunes**		
(Table 9.2.1 cont.)			

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

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

In this chapter, an analysis will be presented of the spatial distribution of major dune types all over the Wadden Sea area, based on a newly developed dune vegetation typology. The results will be evaluated in terms of developments of land-

Table 9.2.1 (cont.)

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

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

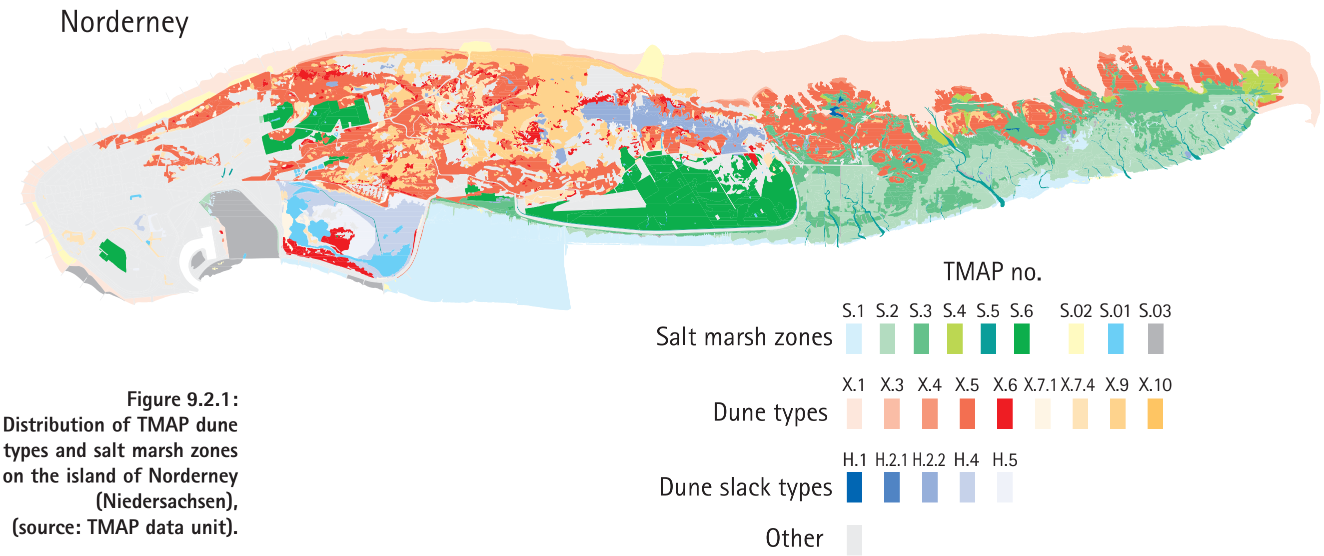


Figure 9.2.1: Distribution of TMAP dune types and salt marsh zones on the island of Norderney (Niedersachsen), (source: TMAP data unit).

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	
Natura 2002-type:	2110	2120	2130	2140		2160	2170	2180		2190	2190	2190	2190	2190	2190	2190	2180	2190	
								(%)											(ha)
NETHERLANDS	**1.9**	**10.8**	**46.4**	**10.4**	**0.8**	**3.9**	**0.1**	**6.6**	**4.4**	**0.0**	**0.4**	**4.0**	**0.7**	**0.5**	**2.1**	**2.5**	**4.2**	**0.2**	**11313.9**
Texel	0.6	14.3	44.5	9.1	0.5	4.6	0.1	4.8	2.1	0.0	0.3	1.7	1.9	0.4	2.4	3.7	8.8	0.2	2865.8
Vlieland	0.2	6.6	48.5	11.8	1.6	1.3	0.0	23.3	0.0	0.2	0.0	2.4	0.1	1.2	2.6	0.1	0.0	0.0	1262.7
Terschelling	3.0	10.7	40.1	18.4	0.0	0.6	0.3	3.8	11.2	0.0	0.5	5.4	0.6	0.6	1.1	2.0	1.4	0.1	3915.3
Ameland	1.6	6.5	60.0	2.2	2.5	2.1	0.0	8.3	0.0	0.0	1.1	6.7	0.0	0.2	4.2	3.0	0.8	0.8	1997.8
Schiermonnikoog	4.0	14.0	46.9	0.0	0.1	17.9	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.6	2.5	12.2	0.0	1272.3
Niedersachsen	**5.3**	**16.5**	**40.2**	**4.4**	**3.2**	**11.3**	**1.5**	**2.5**	**0.6**	**0.2**	**0.7**	**3.6**	**0.9**	**0.2**	**3.5**	**1.3**	**3.2**	**1.0**	**4440.5**
Borkum	10.3	12.8	30.3	1.0	3.6	17.3	0.4	2.7	0.5	0.0	0.9	4.3	1.1	0.1	5.7	1.7	7.1	0.0	1228.6
Juist	1.6	9.0	53.9	3.1	10.1	10.0	0.0	0.0	0.0	2.2	0.9	0.0	3.2	0.0	3.5	2.6	0.0	0.0	436.9
Memmert	15.4	2.8	66.7	0.8	0.2	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.1
Norderney	1.6	21.2	43.8	1.9	0.0	6.6	1.1	2.9	1.5	0.0	0.3	3.5	0.7	0.6	5.4	1.5	4.1	3.2	900.9
Baltrum	1.4	29.8	33.1	0.7	0.8	15.1	1.4	2.3	0.7	0.0	1.9	6.2	0.2	0.0	3.3	2.0	1.1	0.1	248.1
Langeoog	2.9	19.4	28.2	8.7	0.0	14.9	5.9	5.6	0.8	0.0	0.7	7.5	0.0	0.2	1.3	0.5	1.9	1.6	812.5
Spiekeroog	11.3	3.5	63.8	12.4	4.5	3.7	0.0	0.0	0.0	0.0	0.5	0.0	0.1	0.0	0.1	0.1	0.0	0.0	454.3
Wangerooge	0.0	3.2	65.2	10.6	16.2	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.0	0.0	198.8
Mellum	5.8	30.6	61.5	0.0	1.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.9
Minsener Oog	0.0	99.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	82.8
Schleswig-Holstein	**20.3**	**6.5**	**12.6**	**51.6**	**0.0**	**0.0**	**1.0**	**0.3**	**0.0**	**7.6**									**1499.7**
Eiderstedt	0.0	10.7	30.2	24.8	0.0	0.0	1.3	2.7	0.0	30.2									149.0
Föhr	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0									1.0
Amrum	69.0	13.1	2.3	13.8	0.0	0.0	0.0	0.0	0.0	1.8									435.0
Sylt	0.4	2.7	14.7	74.0	0.0	0.0	1.4	0.0	0.0	6.7									914.7
DENMARK	**8.8**	**2.6**	**20.2**	**41.2**	**0.0**	**0.0**	**0.7**	**0.0**	**9.1**	**17.5**									**2645.0**
Römö	13.4	2.5	3.7	47.2	0.0	0.0	0.7	0.0	13.8	18.7									1731.1
Mandö	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0									6.7
Fanö	0.0	0.2	48.2	32.3	0.0	0.0	0.7	0.0	0.0	18.6									746.4
Skallingen	0.2	14.6	64.5	20.7	0.0	0.0	0.0	0.0	0.0	0.0									160.7
WADDEN SEA AREA	**5.0**	**10.6**	**39.0**	**16.2**	**1.2**	**4.7**	**0.6**	**4.3**	**3.9**	**3.0**	**0.4**	**3.1**	**0.6**	**0.3**	**2.0**	**1.7**	**3.1**	**0.3**	**19887.8**

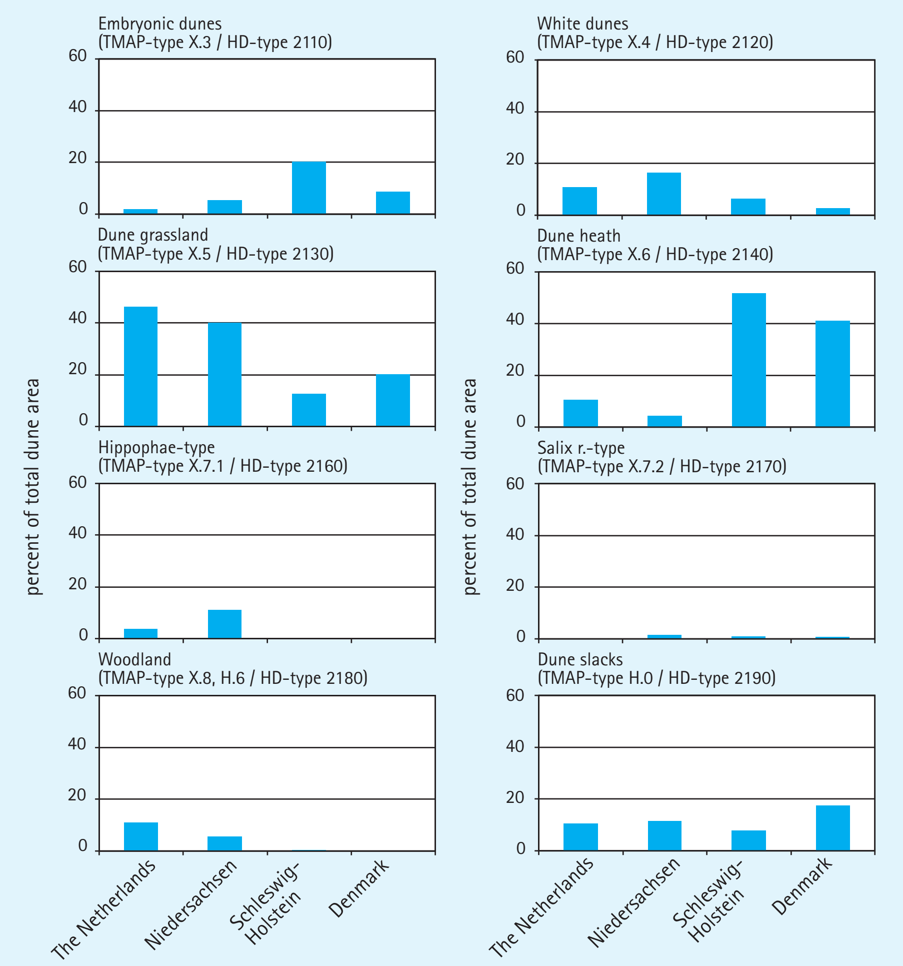


Figure 9.2.2: Relative area (%) of dune types and total area (ha) per country/state.

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 Rottumeroog, 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 albifons*), for which natural dynamics in habitat are of prime importance (see chapter 12.1 'Breeding Birds').

In The Netherlands and Niedersachsen, populations of hen harrier and short-eared owl have their core breeding areas at the Wadden Sea islands, but show opposite trends. Both species are increasing in Niedersachsen and declining in The Netherlands. This decline has often been attributed to the increase of scrub vegetation (as a result of increased atmospheric deposition), which hampers both species' hunting techniques since visibility of main prey like voles deteriorates. However, declines in these species might also be related to decreased populations of rabbits (*Oryctolagus cuniculus*), which are also taken as prey and have recently suffered declines due to the virus 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.

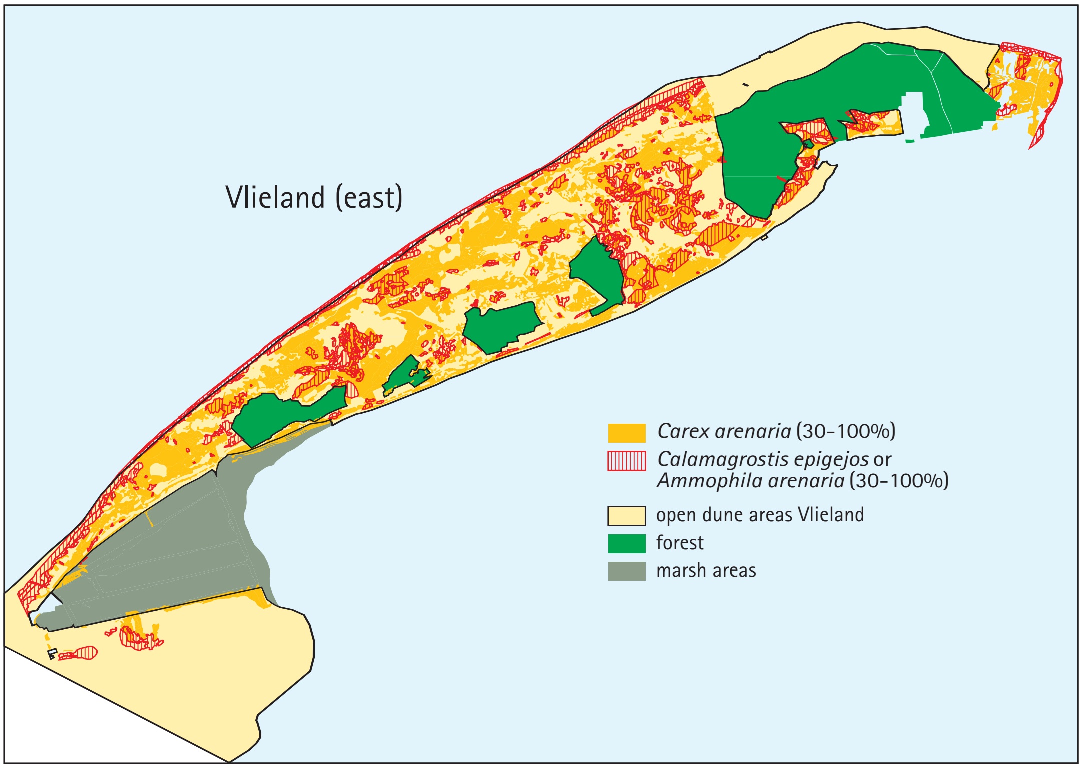
Other qualifying species of the Birds Directive are faced with sharp declines as well, *e.g.* wheatear and red-backed shrike. Recent research showed clear relationships between the occurrence of red-backed shrikes and decreased availability of prey, which in optimal conditions comprises a large variety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

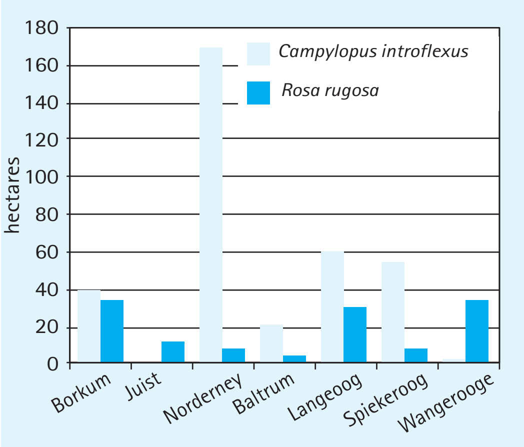


Figure 9.2.4: Occurrence (ha) of neophytes on the islands of Niedersachsen (Hahn, 2005).

9.2.3 Anthropogenic activities as causes of ecological change

9.2.3.1 Coastal protection

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

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

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

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

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

- What is the relationship between different sea defense strategies along the North Sea coastline of the Wadden Sea and the occurrence of young successional stages of dunes?

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

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

9.2.3.2 Atmospheric deposition

Atmospheric deposition of nitrogen is supposed to have contributed to an accelerated succession in the dunes of the Wadden Sea islands, especially in the nutrient poor types of dry dune grassland (TMAP-types X.5.1, X.5.2 and X.5.3), dune heaths

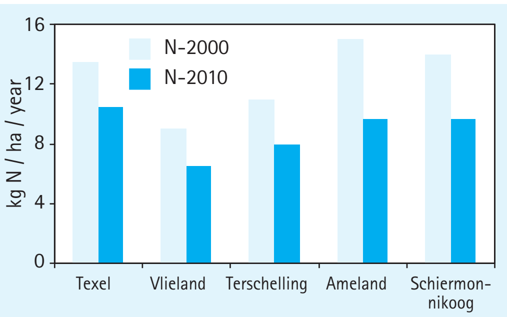


Figure 9.2.5: Nitrogen deposition on the Wadden Sea islands in 2000 and 2010 (from Buijsman, 2003).

(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

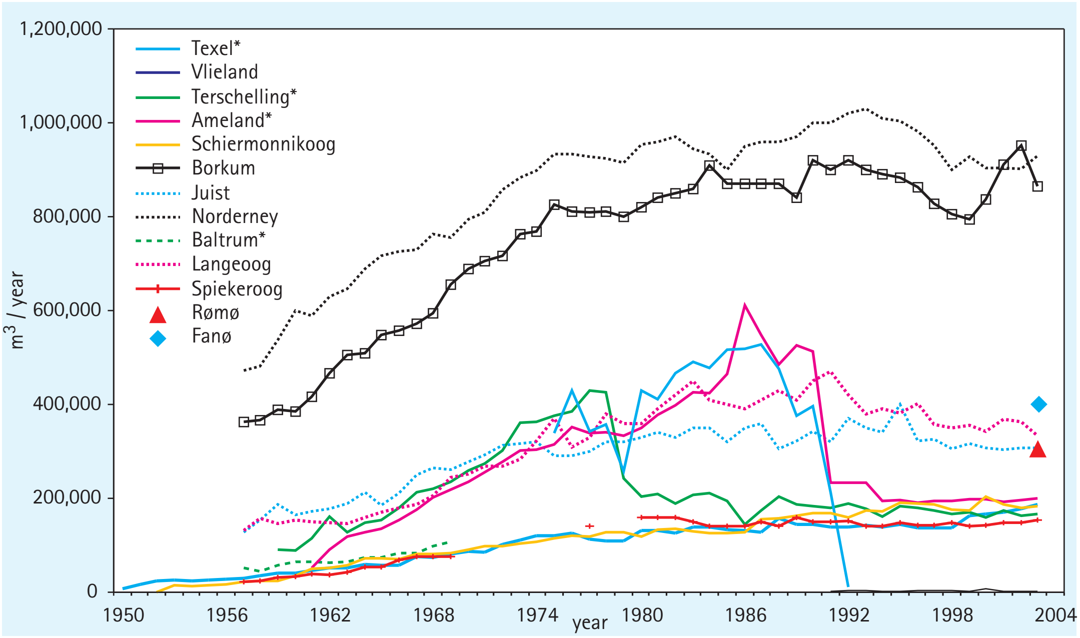


Figure 9.2.6: Groundwater extractions on the Wadden Sea islands (in m^3/year); asterisks indicate islands which now are totally or partly provided with drinking water from the mainland.

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 m^3/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 m^3/year). Instead of building pipelines, on these islands integral water management projects where executed in the early 1990s to develop strategies for minimization of ecological effects. Integral solutions were found in introducing methods to reduce water use, in adopting new methods of extraction and in spreading extraction locations vertically (in different layers) and horizontally in such a way that hydrological regimes at sensitive locations were not or only minimally influenced. On both islands vegetation developments and hydrological regimes are monitored in dune slacks which may still be influenced.

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

In view of the fact that tourists and dune slack vegetation both need groundwater, the interdisciplinary research project 'Sustainable groundwater management in hydrogeological and ecological sensitive areas of the North Sea Coast' (Petersen *et al.*, 2003) was carried out in Niedersachsen. In this project standard values for a sustainable groundwater management were developed by assigning groundwater dependent vegetation units to moisture classes and associated groundwater levels. The resulting data set proved to be a reliable foundation for monitoring systems and scenario studies (Petersen *et al.*, 2001, 2003; Petersen and Sütering, 2003). It enables the evaluation of the effects of groundwater extractions (present or planned) and other hydrological measures on vegetation types. Additionally, the introduced method fulfils the demands of the 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 m^3) and Fanø (302,000 m^3), on the latter island not only for drinking water but also for irrigation of agricultural grounds. Neither for the Danish nor for the Schleswig-Holstein islands is any information available on the possible effects of groundwater withdrawal on sensitive dune slack vegetation.

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

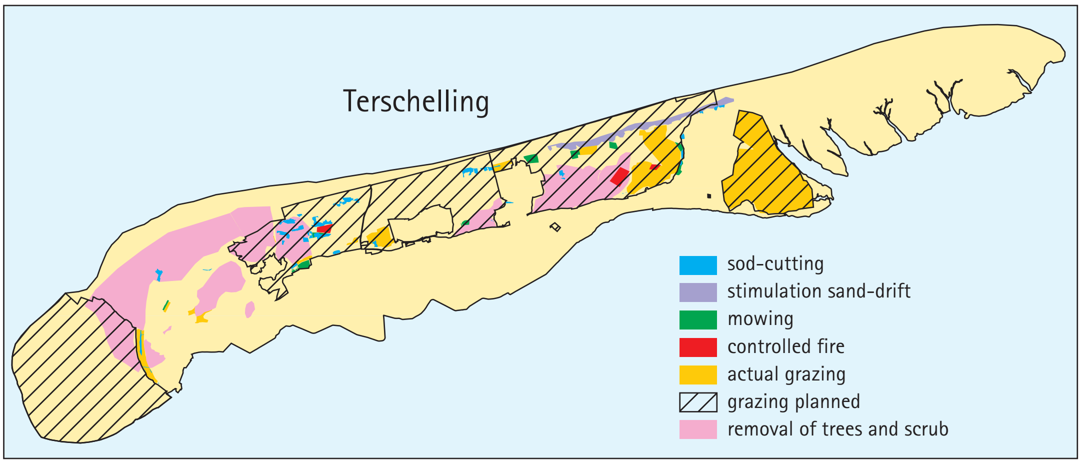


Figure 9.2.7: Nature management measures in the Terschelling dune area. Sod-cutting and stimulating sand-drift were executed in the last 2 decades, controlled fire management was carried out in 2003 and the other activities are permanent or regular. The extension of cattle-grazing areas is planned to 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 ecosytems (*e.g.* nutrient poor dune grasslands), ecotopes with red list species (*e.g.* young dune slacks) or specific biotopes for rare species (*e.g.* reedbeds for birds such as bitterns and marsh harriers and bare or scarcely 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 antropogenic 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-focused realization of the trilateral Targets, though a similar approach in each of the countries is not necessarily preliminary for a most optimal result.

9.2.4 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-inhabitated 'heads' and 'tails' of the islands because coastal protection has recently been stopped almost everywhere along these trajectories. As a consequence areas with dry and wet pioneer stages have expanded here.
2. Along the central parts of the islands the area of dynamic dunes has also increased somewhat because only at some locations were sand dikes still maintained and sand nourishment has taken place. However, the area with embryonic dunes (X.3), white dunes (X.5) and primary dune slacks (H.1) still is very limited. The characteristic hard elements and substantial, densely vegetated sand dikes remaining from previous coastal management appear to restrict dynamic processes to a large extent. Only very locally have some experiments been carried out to stimulate sand blowing.

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 groundwater extraction, causing an accelerated succession to drier communities.
- Accelerated succession in wet and dry dune vegetations is currently being remedied by application of traditional style management measures, restoring successional processes and typical species-rich habitats.
- The Wadden Sea dunes qualify for the EC Birds Directive, especially as a breeding habitat for a number of species. Some species characteristic of open dune areas, however, have strongly declined, due to the development of dense grass-dominated vegetations. Increased scrub vegetation led to a decline in numbers of some characteristic birds of prey on the Dutch islands. Probably also a decreased prey abundance (rabbits) plays a role.
- Various dune types are to be protected with highest priority according to the EC Habitats Directive.

9.2.6 Recommendations

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

- Information on how dry and wet pioneer stages respond to different approaches of coastal defense should be communicated more effectively, and experiments should be carried out on the stimulation of natural dynamics. Special attention should be given to different ways of handling existing hard structures or substantial sand dikes, with the purpose of eliminating their restrictive influence on dynamic processes.
- An inventory should be made of the differences between the Wadden Sea islands in water management and of the ecological consequences. Where severe effects on dune slack vegetation can be demonstrated, measures should be taken to improve the situation.
- A discussion should be held among nature managers and policy makers on views of nature management, especially on differences in strategies aimed at reaching common goals, such as increasing natural dynamics and natural succession and maintaining biodiversity (at least at the level of the Habitats Directive requirements).
- The use of a common monitoring program in the Wadden Sea dunes, recognizing the newly developed TMAP classification for dunes, is a prerequisite for trilateral assessment of dune development and for the detection of trends. Such a program cannot operate without concurrent data collecting on atmospheric deposition, coastal protection measures and water management.
- Research should be stimulated into the possibilities of reestablishing very early pioneer stages in the outer dune area by stimulating dynamics in huge stabilized sand dikes ('constructed' by frequently repeated artificial sand trapping) or even by removing them locally. An integrated geomorphological and ecological approach must result in practical advice

for coastal managers. In addition, more fundamental studies are necessary of the speed and direction of natural succession under different conditions. Such studies should include the lifespan of successional stages, dynamic equilibrium between such stages as influenced by human activities, as well as by large scale processes such as sea level rise and bottom subsidence. The outcome of these studies will contribute to the future policy and management questions concerning the Wadden Sea dunes.

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10. Estuaries

Karel Essink
Heike Büttner
John Frikke
Heiko Leuchs
Harald Marencic
Paddy Walker
Markus A. Wetzel

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.

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

	Varde Å	Eider	Elbe	Weser	Ems
Drainage area above tidal weir (x 10^3 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

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 m^3 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 m^3/yr; data Rijkswaterstaat) and German dredging in 2002 amounted to about 7 million m^3 (Mulder, 2004), present dredging effort is estimated at 9–10 million m^3 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 contaminants mainly from diffuse sources upstream.

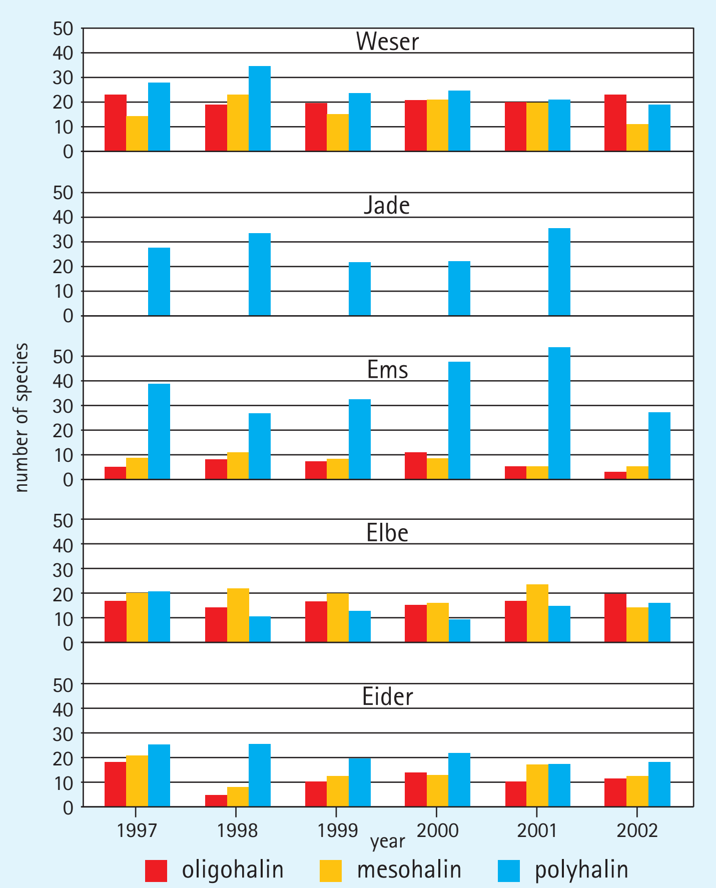
Macrozoobenthos communities have been monitored for all German estuaries by the Federal Institute of Hydrology (BfG, Koblenz) since 1995, and is used as an indicator for the evaluation of environmental conditions. Samples are usually collected once a year in the fall season. In the Ems, Weser and Elbe 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 m^2) 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 linaris* 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 endikement, 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 an 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 km^2, 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 m^3 (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 composition, 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 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 related 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. solida*.

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 solida* 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 m^2 were found at Amrum Bank, whereas at Vogelsand and in the area off Eiderstedt only 1-10 individuals per m^2 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 Frisian 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 Frisian and Danish islands, where up to 200,000

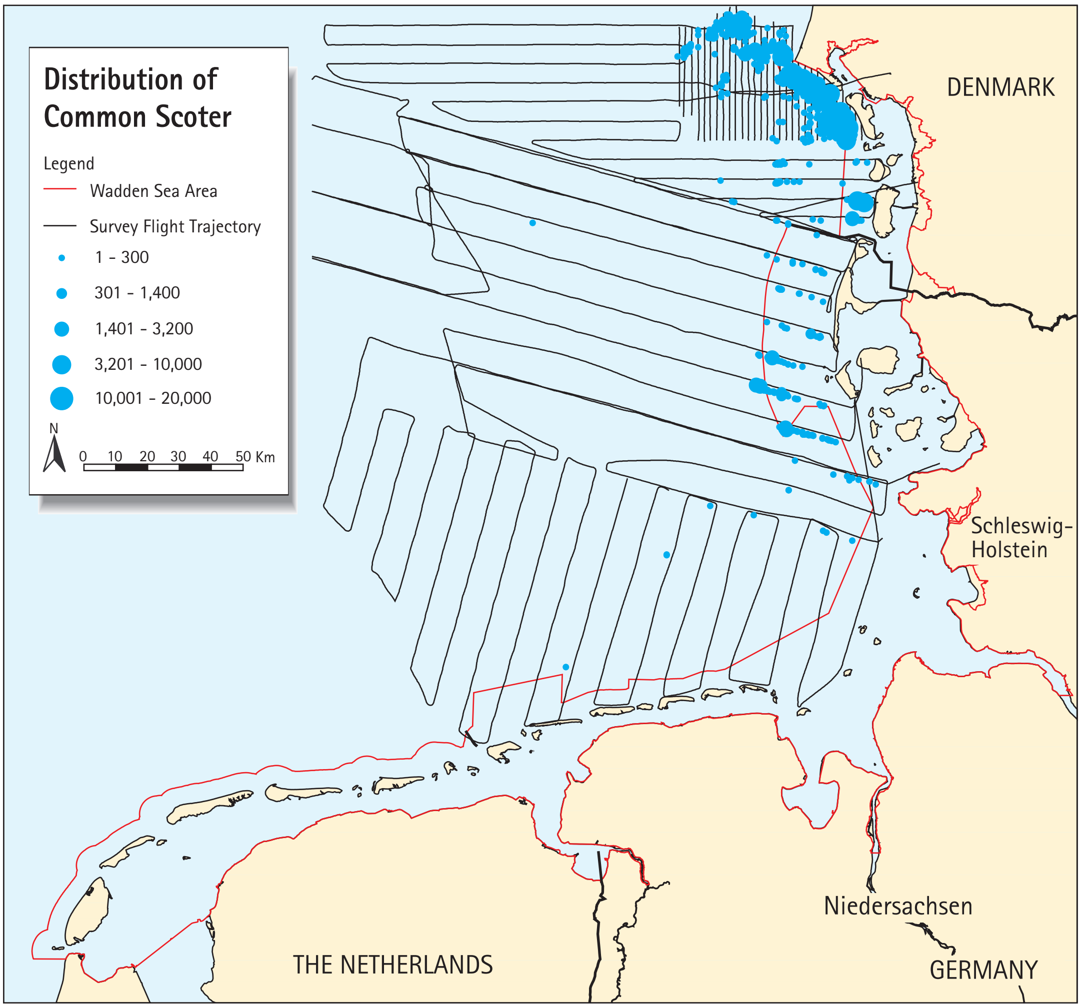

Figure 11.1: Geographical distribution of common scoter (*Melanitta nigra*) in the SE North Sea off the Wadden Sea. The birds were monitored by aircraft in March 2002, and the flight routes are shown. Red line: Wadden Sea Area (Trilateral Cooperation Area). Data source: MINOS (Germany), National Environmental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

Kees Koffijberg
Lieuwe Dijksen
Bernd Hälterlein
Karsten Laursen
Petra Potel
Peter Südbeck
Jan Blew
Kai Eskildsen
Klaus Günther
Hans-Ulrich Rösner
Marc van Roomen

12.1 Breeding Birds

Kees Koffijberg
Lieuwe Dijksen
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

Table 12.1.1.
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 EC Birds Directive	% population NW-Europe	Red List Status	2001 numbers	Trend 1990-2001	Trend 1996-2001
Great cormorant *Phalacrocorax carbo*	-	1-5	-	2,348	+	+
Eurasian spoonbill *Platalea leucorodia*	x	>25	SUS	831	+	+
Shelduck *Tadorna tadorna**	-	5-25	-	6,480	+	+
Common eider *Somateria mollissima**	-	1-5	-	10,500	+	(=)
Red-breasted merganser *Mergus serrator*	-	<1	VUL	44	(+)	no data
Hen harrier *Circus cyaneus*	x	1-5	-	126	(=)	-
Oystercatcher *Haematopus ostralegus**	-	5-25	-	39,928	(=)	-
Avocet *Recurvirostra avosetta**	x	>25	-	10,170	=	(=)
Great ringed plover *Charadrius hiaticula**	-	1-5	VUL	1,093	-	-
Kentish plover *Charadrius alexandrinus**	x	>25	END	340	-	-
Northern lapwing *Vanellus vanellus**	-	1-5	-	11,643	-	(=)
Dunlin *Calidris alpina schinzii*	x	1-5	CRI	24	(-)[1]	no data
Ruff *Philomachus pugnax*	x	<1	CRI	33	(-)[1]	no data
Common snipe *Gallinago gallinago*	-	<1	-	188	(-)[1]	no data
Black-tailed godwit *Limosa limosa*	-	1-5	VUL	2,824	-	(=)
Eurasian curlew *Numenius arquata*	-	<1	-	640	(=)	(=)
Common redshank *Tringa totanus**	-	5-25	-	17,815	(=)	(=)
Turnstone *Arenaria interpres*	-	<1	CRI	1	no data	no data
Mediterranean gull *Larus melanocephalus*	x	1-5	-	9	+	+
Little gull *Larus minutus*	x	<1	SUS	-	no data	no data
Black-headed gull *Larus ridibundus**	-	5-25	-	154,395	(=)	+
Common gull *Larus canus**	-	1-5	-	13,827	+	+
Lesser black-backed gull *Larus fuscus**	-	5-25	-	79,679	+	+
Herring gull *Larus argentatus**	-	5-25	-	78,402	-	(=)
Great black-backed gull *Larus marinus*	-	<1	-	27	+	+
Gull-billed tern *Gelochelidon nilotica*	x	>25	CRI	56	(=)	(=)
Sandwich tern *Sterna sandvichensis**	x	>25	END	17,172	=	(=)
Common tern *Sterna hirundo**	x	5-25	-	13,594	-	+
Arctic tern *Sterna paradisaea**	x	1-5	-	8,464	+	-
Little tern *Sterna albifrons*	x	>25	END	1,099	+	+
Short-eared owl *Asio flammeus*	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 sandvichensis* 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.

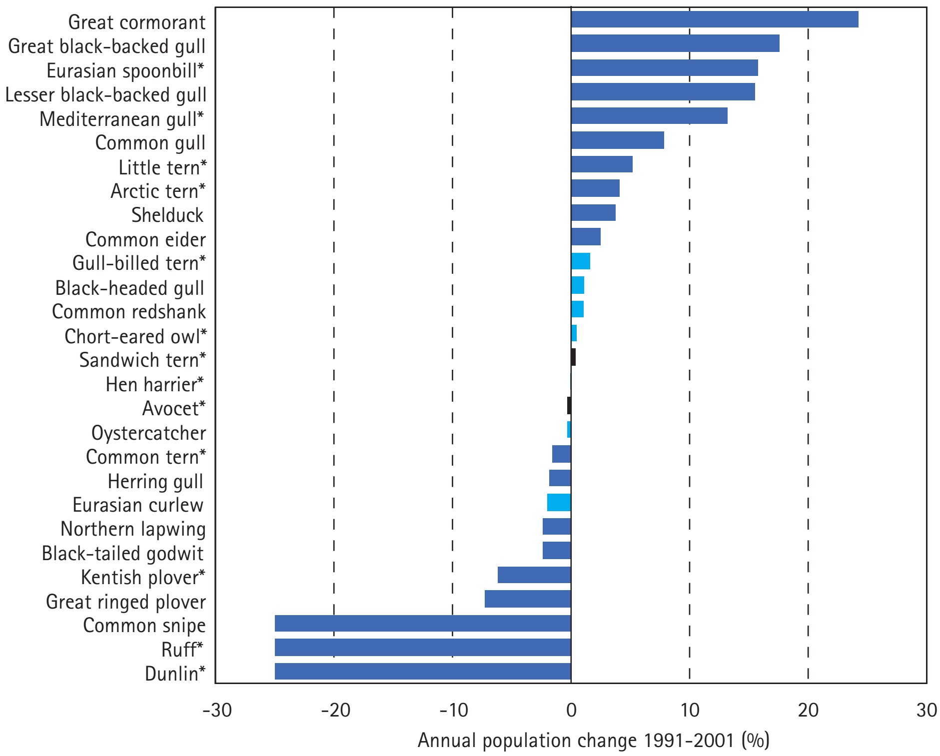


Figure 12.1.1: Summary of trends for breeding birds in the Wadden Sea between 1991-2001. Given is the annual rate of increase or decrease (in %). Non-significant changes are marked in light blue. Black bars indicate species with significant stable trend and annual changes of nearly zero. For common snipe, 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 between 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 edulus* (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).

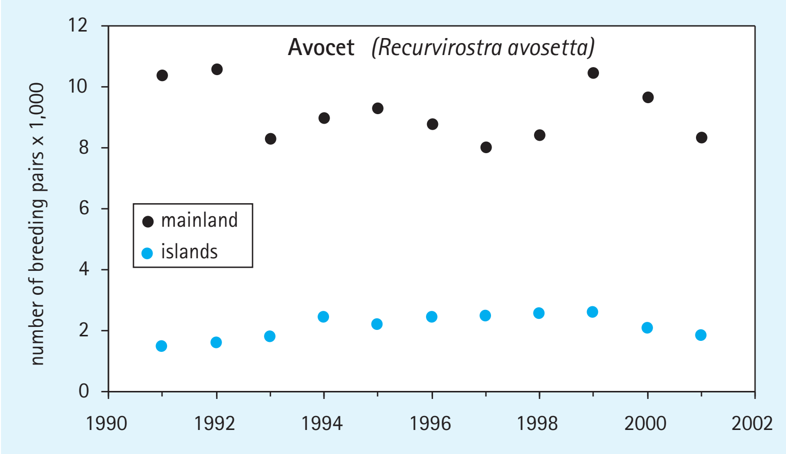
Among the breeding birds assessed, the oystercatcher, avocet, northern lapwing, black-tailed godwit and common redshank occur in highest densities at salt marshes (Rasmussen et al, 2000). Trends for these species indicate declines (northern lapwing, black-tailed godwit) or show stable/

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 development and distribution of, for example, the avocet and black-headed gull recently (Hötker and Segebade, 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.



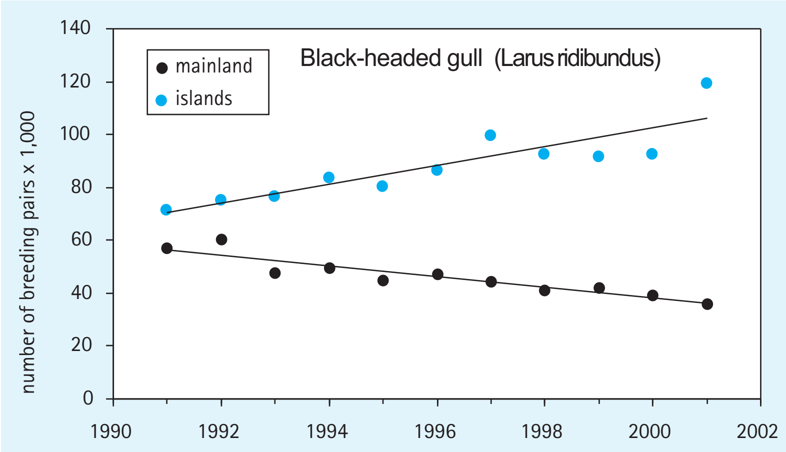


Figure 12.1.2: Population trends of avocets and black-headed gulls breeding at sites along the mainland coast and at islands (incl. outer sands). For black-headed gull, both trends are significant (regression lines for mainland: R^2=0.857, $P<0.001$; islands R^2=0.763, $P<0.001$); for avocet both trends 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 addressed 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

Jan Blew
Kai Eskildsen
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Kees Koffijberg
Karsten Laursen
Petra Potel
Hans-Ulrich Rösner
Marc van Roomen
Peter Südbeck

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

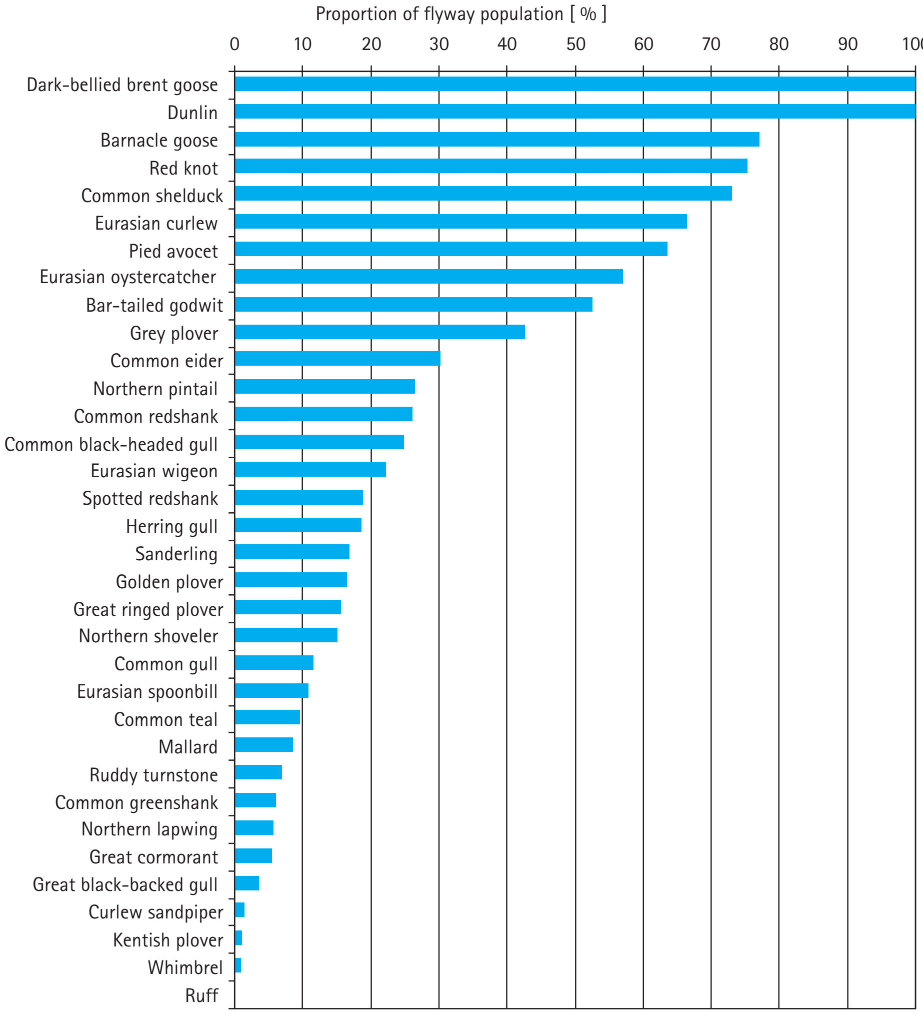
A total of 34 species with 44 distinct geographical populations have to be regarded as typical migratory and wintering birds of the Wadden Sea occurring in high numbers (Table 12.2.1; Blew *et al.*, 2005). Adding up the maximum numbers for each species results in some 6.1 million waterbirds present in 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 fouraging 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, barnacle 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 North-west-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); 0 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* A	W	S	Overall trend** 1992 to 2000	January trend** 1980 to 2000	Flyway population trend*** most recent years
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.

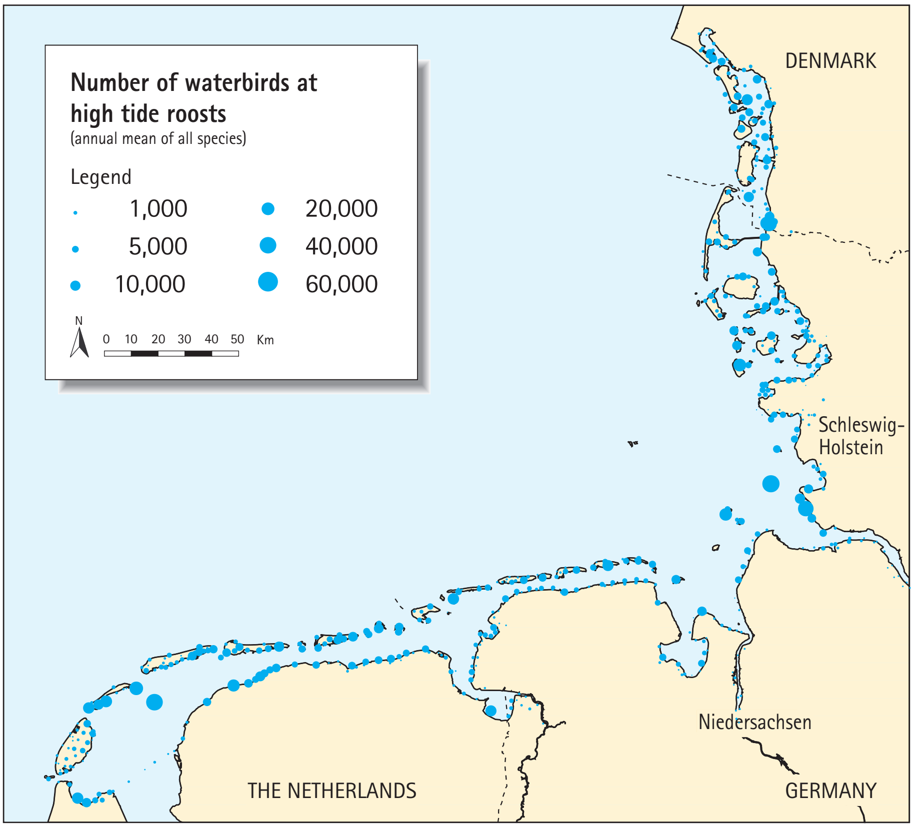


Figure 12.2.2: Overview of high tide roosts in the Wadden Sea, expressed by the sum of all annual means of all relevant species. Large roosts occur in areas close to large intertidal flats and at sites with low anthropogenic disturbance (Koffijberg *et al.*, 2003).

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 agricultural 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.

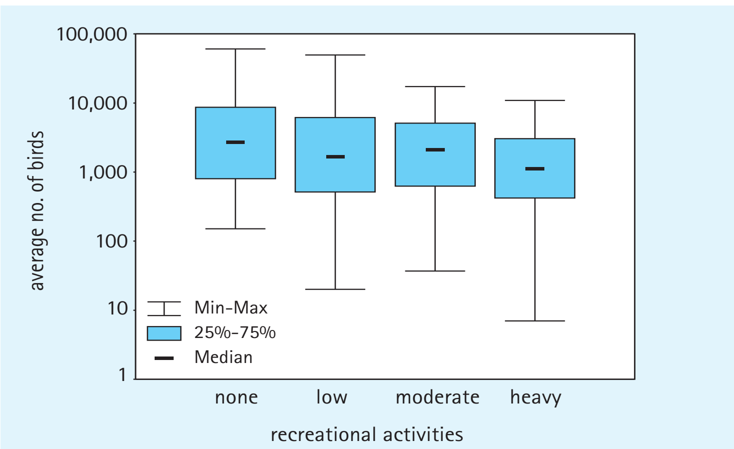


Figure 12.2.3: Bird numbers at high tide roosts in relation to different levels of recreational activities. Although variation is large there is a significant impact of recreational pressure on the number of roosting birds (Koffijberg *et al.*, 2003).

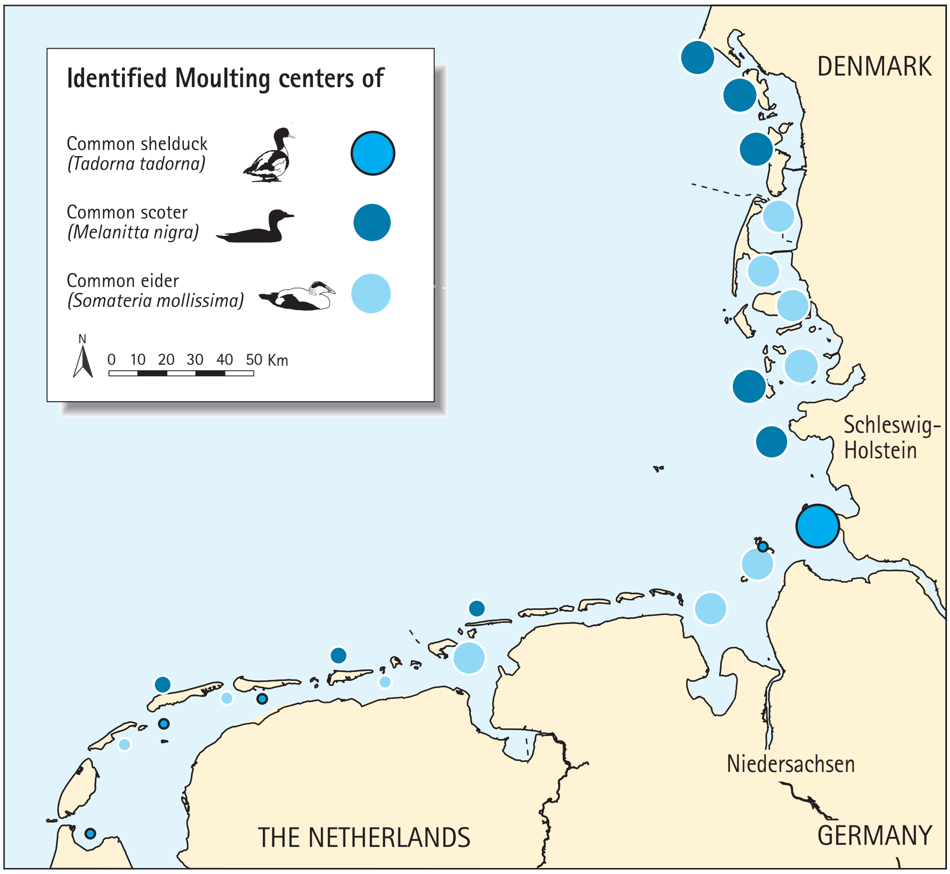


Figure 12.2.4: Moulting distribution of common shelduck, common scoter and common eider (Kempf, 2001; Henning unpubl.; Scheiffarth and Frank, 2005). Size of circles according to the importance of the moulting site for each species.

12.2.4.3 Sufficiently large undisturbed moulting 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 moulting 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. Moulting 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 moulting 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 individuals, synchronously concentrated at this moulting 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 moulting 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 moulting areas are less concentrated compared to those for scoters and shelducks. Moulting 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 moulting 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 moulting, 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 (Ebbinge *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 ultralight 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 (Vliehors 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 approach. 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, trilateral 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 areas 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 (Ebbinge *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 overexploitation. 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 macrozoobenthic communities with regard to assessments of available food stocks for shellfish-eating birds. This will enhance the possibilities 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

Peter J.H. Reijnders
Kai F. Abt
Sophie M.J.M. Brasseur
Kees (C.J.) Camphuysen
Bettina Reineking
Meike Scheidat
Ursula Siebert
Michael Stede
Jakob Tougaard
Svend Tougaard

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).

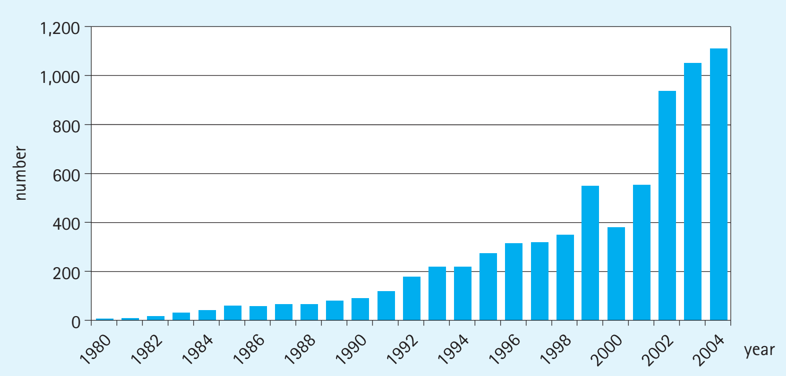
Target
Viable stocks and a natural reproduction capacity of common/harbour seal, grey seal and harbour porpoise in the tidal areas and the offshore zone.

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).

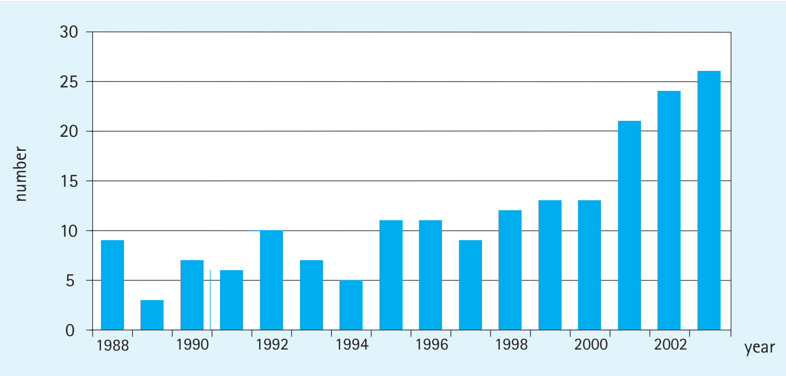
On the Düne isle (Helgoland, German Bight), 120 grey seals were observed in spring 2003 (R. Blädel, pers. comm.; Verein Jordsand, pers. comm.). There are signs of increasing colonies of grey seals elsewhere in German marine waters. In winter 2003, a maximum of 15 grey seals were seen on Borkum Riff and 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, decreas-

Figure 13.2: Minimum annual pup production of grey seals in the Wadden Sea of Schleswig-Holstein (Germany).



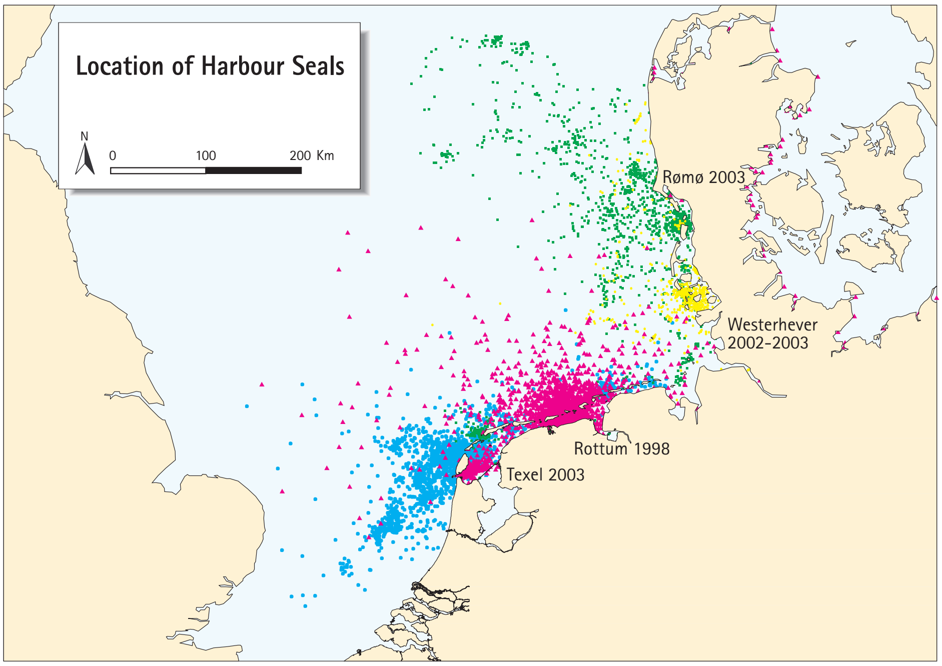


Figure 13.3: Locations of harbour seals revealed through satellite telemetry. Blue: seals tagged close to Texel in 2003; red: seals tagged at Rottum in 1998; green: seals tagged at Rømø in 2002; yellow: seals tagged close to Westerhever in 2002/2003.

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 during 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

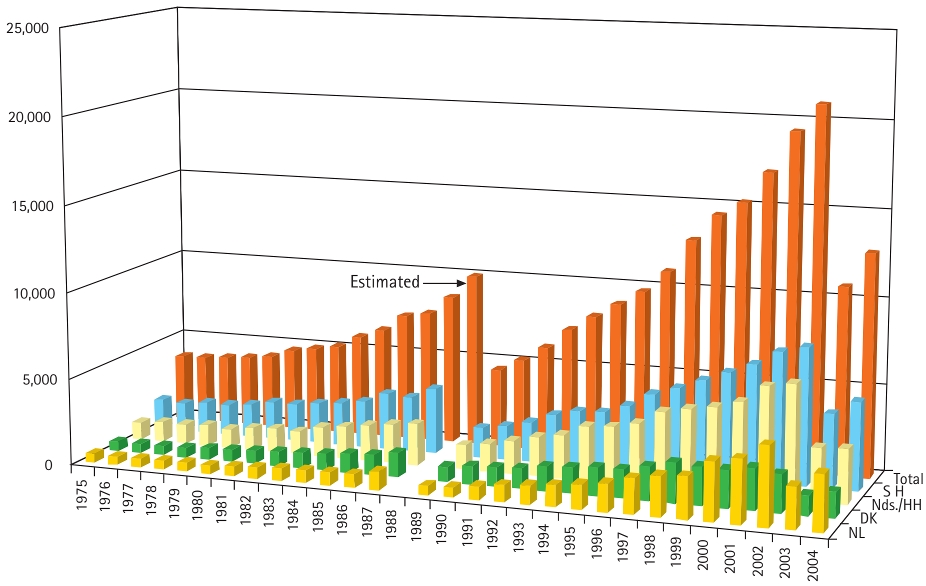
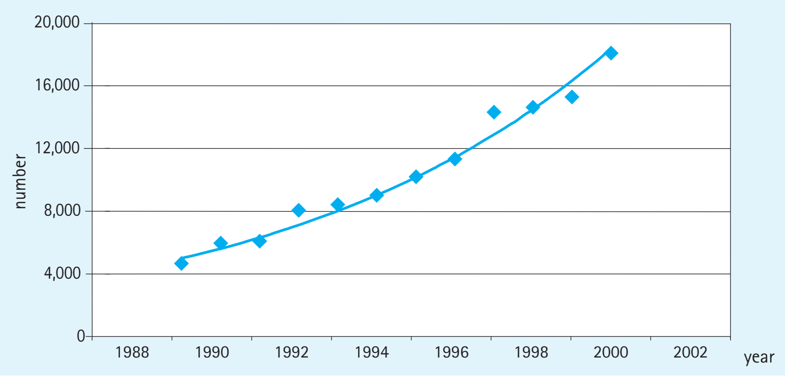


Figure 13.4: Number of harbour seals counted in the different Wadden Sea regions: The Netherlands (NL), Denmark (DK), Niedersachsen and Hamburg (Nds/HH), Schleswig Holstein (SH) and total.

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 13.3.3). 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		1st PDV-epizootic			
1989	13%	28%	38%	21%	4,000
2001	20%	30%	37%	13%	17,900
2002		2nd 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 *Echinophthyrius 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 reconfirmed 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).

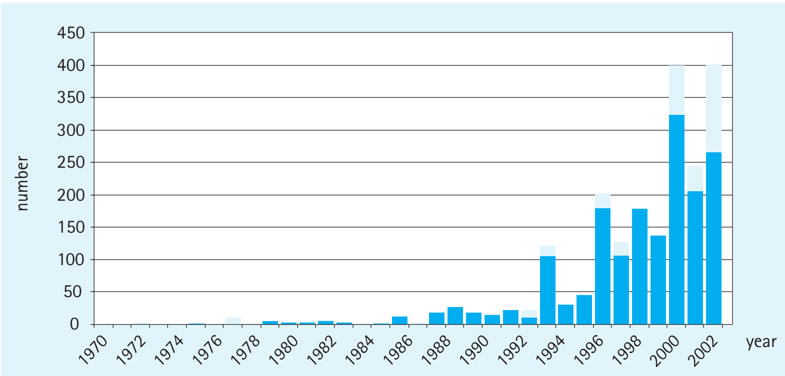
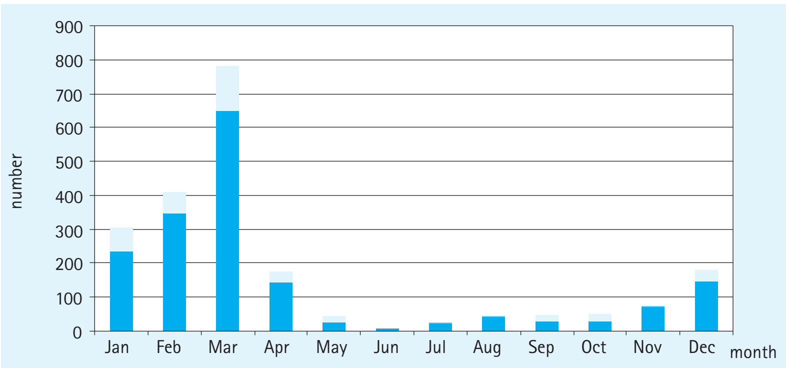


Figure 13.7: Seasonal pattern in sightings of harbour porpoises in The Netherlands, including effort corrected sightings from sea-watching sites (dark blue) and accidental reports (ligth blue).



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 to1995, 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-

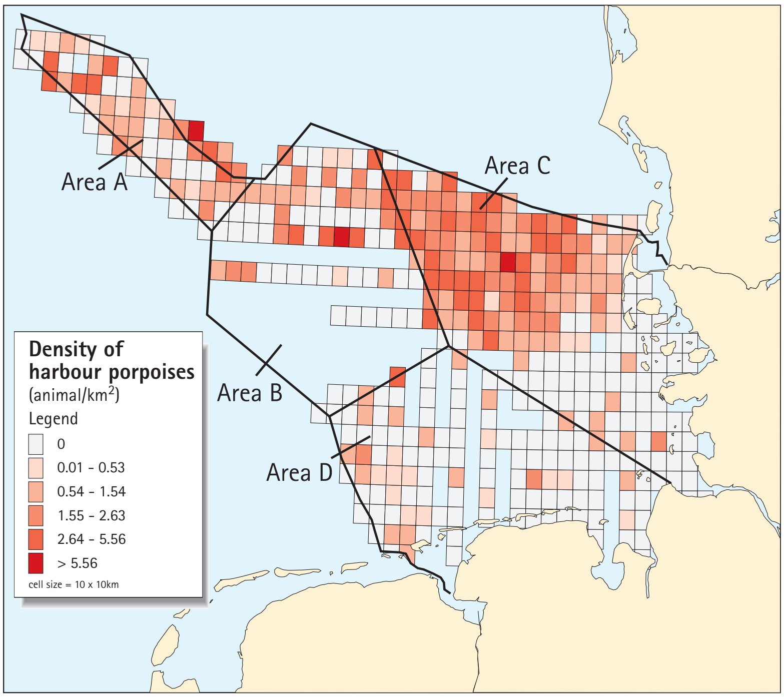


Figure 13.8: Map showing the distribution of harbour porpoises in the German EEZ of the North Sea. Area A = Entenschnabel; B = Offshore; C = Nordfriesland; D = Ostfriesland. For each cell (3' latitude by 6' longitude), density is shown in animals per km². Results are shown of flights conducted under 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.

Area	Size (km²)	2002 Effort (km²)	2002 No. of porp.	2002 Density (animals/km²)	2003 Effort (km²)	2003 No. of porp.	2003 Density (animals/km²)	Abundance per area 2002	Abundance per area 2003	Mean abundance 2002-2003	C.V.
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.

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.

2002	2003	Mean (geometric)	C.V.	C.I. Lower 95%	C.I. 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 porpoise 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.

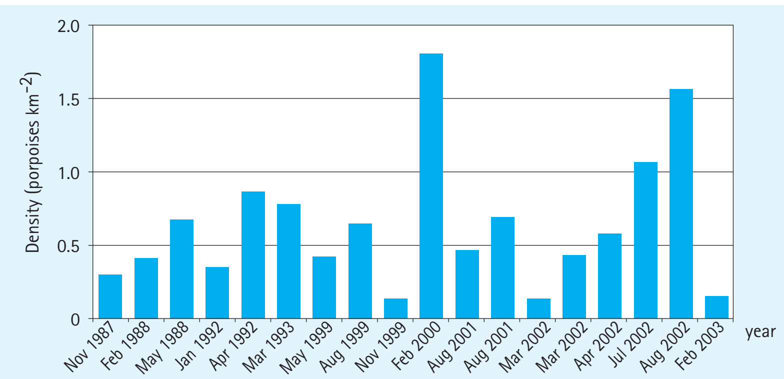


Figure 13.9: Harbour porpoise densities from ship-based visual surveys at Horns Reef, DK. Surveyed areas are not identical and survey conditions (sea state, eye height etc.) vary between surveys. Figures are not corrected for animals missed by the observers (g(0) correction). Data source: Tougaard *et 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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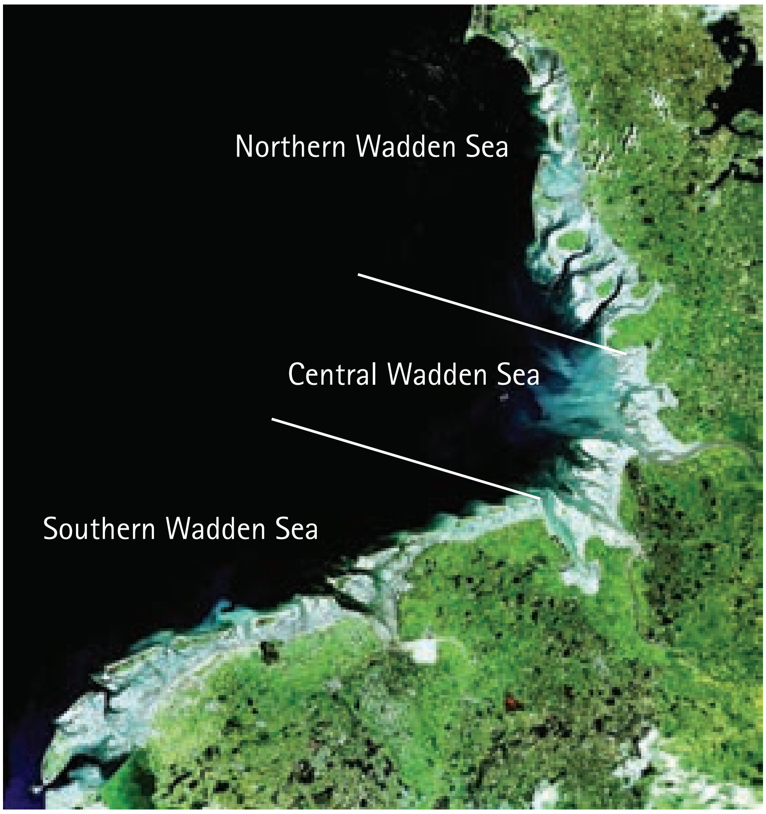
14. Synthesis of Ecosystem Developments



Karsten Reise
Karel Essink
Karsten Laursen

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-

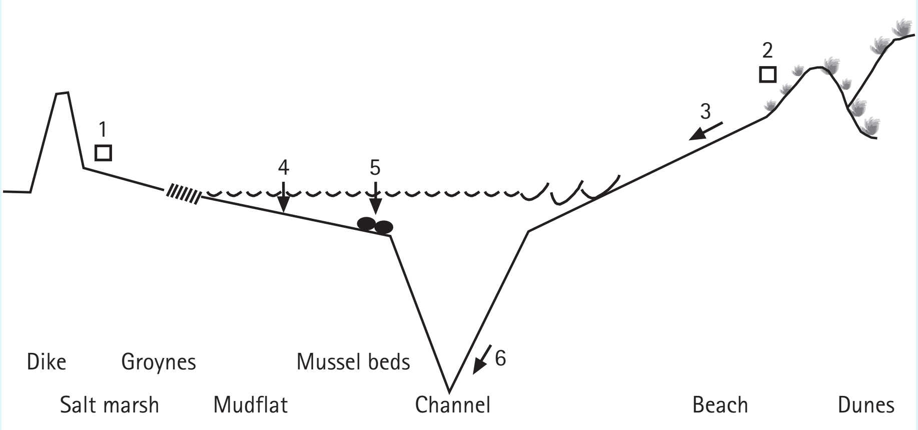


Figure 14.2: Human interference inhibiting and facilitating natural morphodynamics. 1: salt marsh confined between dike and groynes, 2: dune stabilization, 3: nourishment of beaches and foreshore, 4: decreasing fine particle deposition on intertidal flats, 5: dredging and bottom trawling by fishery, 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 ageing. 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 nearshore 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

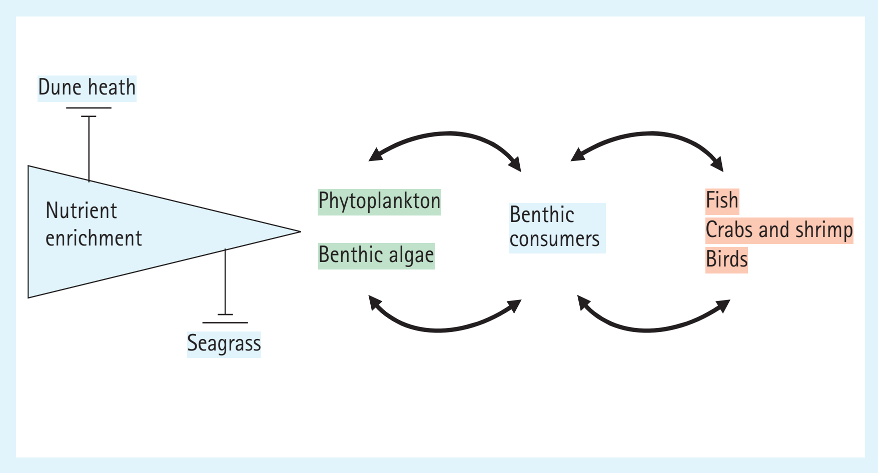


Figure 14.3: Effect chain of nutrient enrichment in the Wadden Sea area: Inhibiting dune heath and seagrass, facilitating phytoplankton and benthic algal growth, and these create reciprocal interactions with various groups of consumers.

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 sabellariid 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 problem 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 region. 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

Karel Essink
Carsten Dettmann
Hubert Farke
Karsten Laursen
Gerold Lüerßen
Harald Marencic
Wim Wiersinga

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 requirements 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 effort 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 polyaromatic 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 decreased, 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 mainland 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 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 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 km^2 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-sluices 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 [, *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-blowing 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-blowing sand, however, are still very limited;
- Eutrophication from atmospheric deposition has caused dense grass vegetations to develop 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 tidal 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 he 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).

Moulting areas

For three species important moulting 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 moulting season.

Moulting 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, moulting 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. Moulting 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 moulting 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 moulting 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 moulting shelduck has been improved through voluntary agreements with different user groups aimed at avoidance of disturbance during the moulting season;
- There are gaps in knowledge regarding specific habitat requirements and sensitivity to disturbance of moulting common scoter and

common eider, preventing an optimal protection of this species;

- Still little information is available on fight 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 seasons. 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:

- $\color{red}\blacktriangledown$ target not reached; development negative,
- $\color{red}\blacktriangle$ target not yet reached; positive development,
- $\color{green}\blacktriangle$ target reached, positive development,
- $\color{green}\blacktriangledown$ 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.	$\color{red}\blacktriangle$	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.	$\color{red}\blacktriangle$	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.	$\color{red}\blacktriangle\blacktriangledown$	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 be10% or less.	$\color{red}\blacktriangle$	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.	$\color{green}\blacktriangle$?	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 naturalvegetation structure of artificial mainland salt marshes. In Denmark, the proportion of intensively grazed salt marshes did not change considerably.
Tidal area – hydrology/ geomorphology and macro-zoobenthos	A natural dynamic situation in the Tidal Area.	▲ ▲	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.
	An increased area of geomorphologically and biologically undisturbed tidal flats and subtidal areas.	?▼	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, *Sabellaria* reefs and *Zostera* fields.	▼ ▲ ▲▲ ▲ ?	No increased area of *Sabellaria* reefs has been reported. The target of increased area of *Zostera* 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.	?▲	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.
	An increased presence of a complete natural vegetation succession.	▲	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 *Spisula* 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 un-disturbed 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	• 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.	• 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	• 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.	• 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	• 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. • Further study and experiments into effective ways of facilitating the development of natural-like drainage creeks.

Issue	Policy & Management	Monitoring & Research
Salt marshes (cont.)	• Cessation of artificial drainage in all salt marshes without any agricultural use, taking care of prevention of water logging 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.	• 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		• 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	• - see under blue mussel beds -	• 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: *Sabellaria* reefs	• 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 constructions in potential reef areas in the Wadden Sea Cooperation Area. New reefs found should be considered for monitoring.
Zostera fields	• 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.	• Restoring of ebb-sluices 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.

Issue	Policy & Management	Monitoring & Research
Blue mussel beds	• 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.	• 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	• Consider appropriate precautionary measures to prevent further introduction of species that may constitute a risk to the Wadden Sea ecosystem.	• 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	• 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.	• 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	• 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.	• 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	• 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.	• 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	• 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 *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.	• 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	• 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.	• 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	• 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 geese management on a flyway level.	• 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	• For optimal conservation of the populations of harbour seal and grey seal, 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.

Issue	Policy & Management	Monitoring & Research
Marine mammals (cont.)	• Improved protection of grey seal colonies in the Wadden Sea and the Offshore Area, including also newly developing colonies.	• 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.
	• 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.	• Organization of cooperative effort for better surveying the occurrence of harbour porpoise inside and outside the Cooperation Area. • Further studies of the impact of fisheries (*e.g.* by-catch) and offshore wind farms on harbour porpoise.

List of Authors

Abt, Kai F.
Samwertstr. 32
D - 24118 Kiel
K.F.Abt@web.de

Bakker, Jan P.
University of Groningen
Community and Conservation Ecology Group
Postbus 14
NL - 9750 AA Haren
j.p.bakker@rug.nl

Bakker, Joop F.
National Institute for Coastal and Marine Management (RIKZ)
Postbus 207
NL - 9750 AE Haren
J.F.Bakker@rikz.rws.minvenw.nl

Becker, Gerd
Bundesamt für Seeschifffahrt und Hydrographie (BSH)
Bernhard-Nocht-Str. 78
D - 20359 Hamburg
gerd.becker@bsh.de

Becker, Peter H.
Institut für Vogelforschung
An der Vogelwarte 21
D - 26386 Wilhelmshaven
peter.becker@ifv.terramare.de

Beusekom, Justus van
Alfred Wegener Institut für Polar- und Meeresforschung
Wattenmeerstation Sylt
Hafenstrasse 43
D-25992 List/Sylt
jbeusekom@awi-bremerhaven.de

Blew, Jan
Theenrade 2
D - 24326 Dersau
Jan.Blew@t-online.de

Bolle, Loes
Netherlands Institute for Fisheries Research (RIVO)
Postbus 68
NL - 1970 AB IJmuiden
loes.bolle@wur.nl

Borchardt, Thomas
Landesamt für den Nationalpark
Schleswig-Holsteinisches Wattenmeer
Schloßgarten 1
D - 25832 Tönning
thomas.borchardt@nationalparkamt.de

Bot, Peter
National Institute for Coastal and Marine Management (RIKZ)
Postbus 20907
NL - 2500 EX Den Haag
P.V.M.Bot@rikz.rws.minvenw.nl

Brasseurr, Sophie M.J.M.
Alterra, Marine Coastal Zone Research
Postbus 167
NL - 1790 AD Den Burg/Texel
Sophie.Brasseur@wur.nl

Brinkman, Bert
Alterra
Postbus 167
NL - 1790 AD Den Burg/Texel
bert.brinkman@wur.nl

Bunje, Jürn
Nationalparkverwaltung Niedersächsisches Wattenmeer
Virchowstr. 1
D - 26382 Wilhelmshaven
juern.bunje@nlpv-wattenmeer.niedersachsen.de

Büttner, Heike
Bundesanstalt für Gewässerkunde
Postfach 200253
D - 56002 Koblenz
buettner@bafg.de

Buschbaum, Christian
Alfred Wegener Institut für Polar- und Meeresforschung
Wattenmeerstation Sylt
Hafenstr. 43
D - 25992 List/Sylt
cbuschbaum@awi-bremerhaven.de

Camphuysen, Kees (C.J.)
NIOZ
Postbus 59
NL - 1790 AB Den Burg/Texel
camphuys@nioz.nl

Dankers, Norbert
Alterra
Postbus 167
NL - 1790 AD Den Burg/Texel
norbert.dankers@wur.nl

Dettmann, Carsten
Bundesministerium für Umwelt, Naturschutz und
Reaktorsicherheit (BMU) Referat NI4
Postfach12 06 29
D - 53048 Bonn
carsten.dettmann@bmu.bund.d

Dijkema, Kees
Alterra
Postbus 167
NL - 1790 AD Den Burg/Texel
Kees.Dijkema@wur.nl

Dijksen, Lieuwe
Fonteinsweg 9
NL - 1797 RK Den Hoorn Texel
Lieuwe.Dijksen@sovon.nl

Eekhof, Hugo
Stuurgroep Waddenprovincies
Postbus 20120
NL - 8900 HM Leeuwarden
h.eekhof@fryslan.nl

Eskildsen, Kai
Landesamt für den Nationalpark
Schleswig-Holsteinisches Wattenmeer
Schloßgarten 1
D - 25832 Tönning
kai.eskildsen@nationalparkamt.de

Essink, Karel
National Institute for Coastal and Marine Management (RIKZ)
Postbus 207
NL - 9750 AE Haren
K.Essink@rikz.rws.minvenw.nl

Fenger, Jes
Danmarks Miljøundersøgelser (NERI)
Afdeling for Atmosfærisk Miljø
Frederiksborgvej 399
DK - 4000 Roskilde
jfe@dmu.dk

Farke, Hubert
Nationalparkverwaltung Niedersächsisches Wattenmeer
Virchowstr. 1
D - 26382 Wilhelmshaven
hubert.farke@nlpv-wattenmeer.niedersachsen.de

Fleet, David M.
Landesamt für den Nationalpark
Schleswig-Holsteinisches Wattenmeer
Schloßgarten 1
D - 25832 Tönning
david.fleet@nationalparkamt.de

Frikke, John
Ribe Amt
Sorsigvej 35
DK - 6760 Ribe
jfr@ribeamt.dk

Gätje, Christiane
Landesamt für den Nationalpark
Schleswig-Holsteinisches Wattenmeer
Schloßgarten 1
D - 25832 Tönning
christiane.gaetje@nationalparkamt.de

Göbel, Jeanette
Landesamt für Natur und Umwelt des Landes
Schleswig-Holstein
Hamburger Chaussee 25
D - 24220 Flintbek
jgoebel@lanu.landsh.de

Günther, Klaus
Schutzstation Wattenmeer
in NationalParkHaus Hafen Husum
Hafenstraße 3
D - 25813 Husum
k.guenther@schutzstation-wattenmeer.de

Hanslik, Michael
Niedersächsischer Landesbetrieb für Wasserwirtschaft
Küsten- und Naturschutz (NLWKN)
Betriebsstelle Norden-Norderney
An der Mühle 5
D - 26548 Norderney
Michael.Hanslik@nlwkn-ny.niedersachsen.de

Hälterlein, Bernd
Landesamt für den Nationalpark
Schleswig-Holsteinisches Wattenmeer
Schloßgarten 1
D - 25832 Tönning
bernd.haelterlein@nationalparkamt.de

Hähne, Karl
Behörde für Stadtentwicklung und Umwelt, Hamburg
Billstr. 84
D - 20539 Hamburg
karl.haehne@bsu.hamburg.de

Hecker, Norbert
Nationalparkverwaltung Niedersächsisches Wattenmeer
Virchowstr. 1
D - 26382 Wilhelmshaven
norbert.hecker@nlpv-wattenmeer.niedersachsen.de

Herlyn, Marc
Niedersächsischer Landesbetrieb für Wasserwirtschaft,
Küsten- und Naturschutz (NLWKN)
Betriebsstelle Brake-Oldenburg
An der Mühle 5
D - 26548 Norderney
marc.herlyn@nlwkn-ny.niedersachsen.de

Heuvel-Greve, Martine van den
National Institute for Coastal and Marine Management (RIKZ)
Postbus 8039
NL - 4330 EA Middelburg
M.J.vdHeuvel-Greve@rikz.rws.minvenw.nl

Hofstede, Jacobus
Innenministerium des Landes Schleswig-Holstein
Referat IV 83 Küstenschutz und Häfen
Postfach 7125
D - 24171 Kiel
Jacobus.Hofstede@im.landsh.de

Kellermann, Adolf
ICES
H. C. Andersens-Boulevard 44-46
DK - 1553 Copenhagen V
adi@ices.dk

Jager, Zwanette
National Institute for Coastal and Marine Management (RIKZ)
Postbus 207
NL - 9750 AE Haren
z.jager@rikz.rws.minvenw.nl

Janssen, Gerard
National Institute for Coastal and Marine Management (RIKZ)
Postbus 207
NL - 9750 AE Haren
G.M.Janssen@rikz.rws.minvenw.nl

Jong, Dick de
National Institute for Coastal and Marine Management (RIKZ)
Postbus 8039
NL - 4330 EA Middelburg
D.J.dJong@rikz.rws.minvenw.nl

Katwijk, Marieke van
Radboud University Nijmegen
Dept. Environmental Science
Postbus 9010
NL - 6500 GL Nijmegen
mvkatwyk@sci.kun.nl

Kers, Bas
Ministry of Transport, Public Works and Water Management
Geo- Information and ICT Department
Postbus 5023
NL - 2600 GA Delft
a.s.kers@agi.rws.minvenw.nl

Körber, Peter
Behörde für Stadtentwicklung und Umwelt Hamburg
Nationalparkverwaltung
Billstr. 84
D - 20539 Hamburg
peter.koerber@bsu.hamburg.de

Kohlus, Jörn
Landesamt für den Nationalpark
Schleswig-Holsteinisches Wattenmeer
Schloßgarten 1
D - 25832 Tönning
joern.kohlus@nationalparkamt.de

Koffijberg, Kees
SOVON Dutch Centre for Field Ornithology
Rijksstraatweg 178
NL - 6573 DG Beek-Ubbergen
kees.koffijberg@sovon.nl
kees.koffijberg@t-online.de

Kristensen, Per Sand
Danmarks Fiskeriundersøgelser
Charlottenlund Slot
DK - 2920 Charlottenlund
psk@dfu.min.dk

Lammerts, Evert Jan
Staatsbosbeheer Friesland
Postbus 1726
NL - 8910 CA Leeuwarden
E.Lammerts@staatsbosbeheer.nl

Laursen, Karsten
Danmarks Miljøundersøgelser, NERI
Dep. Wildlife Biology and Biodiversity, Kalø
Grenåvej 12
DK - 8410 Rønde
kl@dmu.dk

Lenhart, Hermann-Josef
Institut für Meereskunde
Universität Hamburg
Bundesstr. 53
D - 20146 Hamburg
lenhart@ifm.uni-hamburg.de

Leuchs, Heiko
Bundesanstalt für Gewässerkunde
Postfach 200253
D - 56002 Koblenz
leuchs@bafg.de

Lüerßen, Gerold
Common Wadden Sea Secretariat
Virchowstr. 1
D - 26382 Wilhelmshaven
luerssen@waddensea-secretariat.org

Marencic, Harald
Common Wadden Sea Secretariat
Virchowstr. 1
D - 26382 Wilhelmshaven
marencic@waddensea-secretariat.org

Menn, Iris
Alfred-Wegener-Institut für Polar und Meeresforschung
Wattenmeerstation Sylt
D - 25992 List
imenn@awi-bremerhaven.de

Millat, Gerald
Nationalparkverwaltung Niedersächsisches Wattenmeer
Virchowstr. 1
D - 26382 Wilhelmshaven
gerald.millat@nlpv-wattenmeer.niedersachsen.de

Mulder, Saskia
National Institute for Coastal and Marine Management (RIKZ)
Postbus 207
NL - 9750 AE Haren
s.mulder@rikz.minvenw.nl

Muñoz Cifuentes, Jacqueline
Institut für Vogelforschung
An der Vogelwarte 21
D - 26386 Wilhelmshaven

Nehls, Georg
BioConsult SH
Alte Landstrasse 2
D - 25875 Hockensbüll
georg.nehls@t-online.de

Neudecker, Thomas
Bundesforschungsanstalt für Fischerei
Institut für Seefischerei
Palmaille 9
D - 22767 Hamburg
thomas.neudecker@ish.bfa-fisch.de

Oost, Albert P.
National Institute for Coastal and Marine Management (RIKZ)
Postbus 207
NL - 9750 AE Haren
A.P.Oost@rikz.rws.minvenw.nl

Pätsch, Johannes
Institut für Meereskunde
Universität Hamburg
Bundesstr. 53
D - 20146 Hamburg
paetsch@ifm.uni-hamburg.de

Peperzak, Louis
National Institute for Coastal and Marine Management (RIKZ)
Postbus 8039
NL - 4330 EA Middelburg
L.Peperzak@rikz.rws.minvenw.nl

Petenati, Thorkild
Landesamt für Natur und Umwelt des Landes
Schleswig-Holstein
Hamburger Chaussee 25
D - 24220 Flintbek
tpetenat@lanu.landsh.de

Petersen, Jörg
Konrad-Adenauer-Str. 6
D - 31139 Hildesheim
petersen@nature-consult.de

Piontkowitz, Thorsten
Kystinspektoratet
P.O. Box 100
DK - 7620 Lemvig
tpi@kyst.dk

Potel, Petra
Nationalparkverwaltung Niedersächsisches Wattenmeer
Virchowstr. 1
D - 26382 Wilhelmshaven
petra.potel@nlpv-wattenmeer.niedersachsen.de

Raagaard, Karen
Sønderjyllands Amt
Jomfrustien 2
DK - 6270 Tønder
Karen_Raagaard@sja.dk

Reijnders, Peter J.H.
Alterra, Marine Coastal Zone Research
Postbus 167
NL - 1790 AD Den Burg/Texel
Peter.Reijnders@wur.nl

Reineking, Bettina
Common Wadden Sea Secretariat
Virchowstr. 1
D - 26382 Wilhelmshaven
reineking@waddensea-secretariat.org

Reise, Karsten
Alfred Wegener Institut für Polar- und Meeresforschung
Wattenmeerstation Sylt
D - 25992 List / Sylt
kreise@awi-bremerhaven.de

Rösner, Hans-Ulrich
WWF - Projektbüro Wattenmeer
in NationalParkHaus Hafen Husum
Hafenstraße 3
D - 25813 Husum
roesner@wwf.de

Roomen, Marc van
SOVON Dutch Centre for Field Ornithology
Rijksstraatweg 178
NL - 6573 DG Beek-Ubbergen
marc.vanroomen@sovon.nl

Ruth, Maarten
Amt f. ländliche Räume Kiel
ASt. 6 (Fischerei)
Postfach 24028
D - 24148 Kiel
Maarten.Ruth@Fischerei.ALR-Kiel.landsh.de

Schans, Henni
Rijkswaterstaat Directie Noord- Nederland
Postbus 2301
NL - 8901 JH Leeuwarden
h. schans@dnn.rws.minvenw.nl

Schanz, Anja
Alfred Wegener Institut für Polar- und Meeresforschung
Wattenmeerstation Sylt
D - 25992 List / Sylt
aschanz@awi-bremerhaven.de

Scheidat, Meike
Forschungs- u. Technologiezentrum Westküste (FTZ)
Universität Kiel
Werftstr. 6
D - 25761 Büsum
scheidat@ftz-west.uni-kiel.de

Siebert, Ursula
Forschungs- u. Technologiezentrum Westküste (FTZ)
Universität Kiel
Werftstr. 6
D - 25761 Büsum
ursula.siebert@ftz-west.uni-kiel.de

Skov, Henrik
DHI Water & Environment
Agernallee 11
DK - 2970 Horsholm
hsk@dhi.dk

Stede, Michael
LAVES
Veterinärinstitut für Fische und Fischwaren
Schleusenstr.
D - 27472 Cuxhaven
Michael.Stede@laves.niedersachsen.de

Steenbergen, Josien
Netherlands Institute for Fisheries Research (RIVO)
Centre for Shellfish Research (CSO)
P.O. Box 77
NL - 4400 AB Yerseke
Josien.Steenbergen@wur.nl

Stock, Martin
Landesamt für den Nationalpark
Schleswig-Holsteinisches Wattenmeer
Schloßgarten 1
D - 25832 Tönning
martin.stock@nationalparkamt.de

Südbeck, Peter
Niedersächsischer Landesbetrieb für Wasserwirtschaft,
Küsten- und Naturschutz (NLWKN)
Geschäftsbereich Naturschutz
Göttingerstr. 14
D - 30449 Hannover
peter.suedbeck@nlwkn-h.niedersachsen.de

Thorenz, Frank
Niedersächsischer Landesbetrieb für Wasserwirtschaft,
Küsten- und Naturschutz (NLWKN)
Betriebstelle Norden- Norderney
Jahnstraße 1
D - 26506 Norden
frank.thorenz@nlwkn-nor.niedersachsen.de

Tougaard, Jakob
National Environmental Research Institute (NERI)
Frediksborgvej 399
P.O. Box 359
DK - 4000 Roskilde
jat@dmu.dk

Tougaard, Svend
Fiskeri-og Søfartsmuseet
Tarphagevej 2
DK - 6710 Esbjerg V
st@fimus.dk

Vethaak, Dick
National Institute for Coastal and Marine Management (RIKZ)
Postbus 8039
NL - 4330 EA Middelburg,
Email: a.d.vethaak@rikz.rws.minvenw.nl

Vlas, Jaap de
National Institute for Coastal and Marine Management (RIKZ)
Postbus 207
NL - 9750 AE Haren
J.dVlas@rikz.rws.minvenw.nl

Vorberg, Ralf
Marine Science Service
Fasanenstieg 12
D - 21521 Dassendorf
rvorberg@aol.com

Walker, Paddy
National Institute for Coastal and Marine Management (RIKZ)
Postbus 207
NL - 9750 AE Haren
p.walker@rikz.rws.minvenw.nl

Wehrman, Achim
Inst. f. Meeresgeologie u. Meeresbiologie Senckenberg
Schleusenstr. 39 a
D - 26382 Wilhelmshaven
achim.wehrmann@senckenberg.de

Weisse, Ralf
GKSS Forschungszentrum Geesthacht GmbH
Institut für Küstenforschung
Max-Planck-Str. 1
D - 21502 Geesthacht
Ralf.Weisse@gkss.de

Wetzel, Markus A.
Bundesanstalt für Gewässerkunde
Postfach 200253
D - 56002 Koblenz
wetzel@bafg.de

Wiersinga, Wim
Expertisecentrum LNV
Ministerie van Landbouw, Natuur en Voedselkwaliteit (LNV)
Postbus 482
NL - 6710 BL Ede
w.a.wiersinga@eclnv.agro.nl

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