6. Assessment and Recommendations

6.1 Introduction

In this final chapter, a general evaluation and assessment of the basic material from chapters 1 to 5 is presented. The chapter is structured according to the Wadden Sea habitats as entailed in the Wadden Sea Plan. It concerns the Tidal Area, Salt Marshes, Estuaries, Beaches and Dunes, the Offshore Zone, and the Rural Area. In addition, sections about the Quality of Water, Sediment and Biota and Birds and Marine Mammals are included. The habitat type 'Rural Area' is addressed in the 'Birds' Section.

In each section, first, a summary of the main findings from the previous chapters is given. Next, the common trilateral Targets, relevant for the section under consideration, are evaluated, and recommendations for management, monitoring and research given. It is stressed here that the scientific evaluation of the Targets is limited by a number of factors. The most important is that the Targets are of a general nature and provide, in most cases, not a desired end-situation. They indicate the policy direction to be followed by the three Wadden Sea states.Moreover, in many cases, we lack the proper data basis, both for an analysis of the present and the past situation, so that it is not possible to evaluate progress or decline. Also, the TMAP is only in its first phase of implementation and, with regard to the Target requirements, not yet sufficiently elaborated.

The interpretation and evaluation of monitoring data for several parametersis still severely hampered by different national monitoring methodologies and insufficient suitable data.

An important aspect in the assessment is the comparability of data. Besides harmonization of methods, standardization can be an important tool as was demonstrated for sediments.

The most time consuming parts of the QSR analysis and evaluation procedure have been the exchange of data between the participating countries and institutes and the formatting of the data. The TMAP tool for data exchange should be implemented as soon as possible, thus reducing the preparation time by approximately one year.

In the TMAP monitoring of bird eggs, it was decided to collect eggs by national effort but to carry out sample preparation and analysis at a central institute. The advantages of this approach have proven to be great and should be taken into consideration in the further elaboration of the trilateral monitoring strategy, also for other parameters and matrices.

6.2 Quality of Water, Sediment and Biota

6.2.1 Nutrients and Eutrophication

Inputs and concentrations

In the period 1985-1996, total phosphorus, phosphate and ammonia loads of Lake IJssel, Ems (ammonia only) and the Elbe decreased.

For total nitrogen and nitrate, an ongoing load reduction in the period 1985-1996 could not be observed, but the 1995 nitrogen and nitrate loads of the Elbe were lower than the 1985 loads. Both were years with a high run-off. The riverine reductions can be attributed to the progressive implementation of wastewater purification schemes.

In the period 1985-1996, a significant decrease in phosphate concentrations occurred in the southwestern Wadden Sea from Den Helder to the Jadebusen and in the northeastern Wadden Sea from the Eider estuary to the Sylt-Rømø area. A significant decrease in dissolved inorganic nitrogen (DIN) concentrations was found for the Ems Estuary (ammonia) and the Niedersachsen Wadden Sea (both ammonia and nitrate).

Phenomena related to eutrophication

As possible negative effects of the high nutrients loads entering the Wadden Sea, the 1993 QSR mentioned an increase in toxic and nuisance phytoplankton blooms, an increase in biomass and abundance of macrozoobenthos, a shift in species diversity and composition, increasing abundance of macroalgae and oxygen deficiency in the sediment surface.

The relationship between nutrient loads and the above listed phenomena has, however, proven to be even more complex than already thought.

Primary production

The observed reduction in dissolved phosphorus and, in some cases, nitrogen compounds has not caused a reduction in average chlorophyll levels in any part of the Wadden Sea.

Four possible causes for the continuing high primary production in the Wadden Sea are given, namely improved water transparency, release of phosphorus from the sediment, import of organic material from the North Sea and nitrogen as the limiting factor. Evaluation of the nutrient data indicated that, at least in the areas without a direct fresh water input, the nutrient efflux of nutrients from the sediment plays an important role. Remineralization of detritus can, thus, be considered an important source of nutrients.

Mussel beds increase the turnover rate of organic matter and, in this way, cause a higher yearly primary production than has been assumed until now. On the other hand, mussel beds may stimulate denitrification and, in this way, reduce the available amount of dissolved inorganic nitrogen. It is unclear whether the impact of mussel beds on the yearly primary production is positive or negative

Toxic and nuisance algae

The reduction in the inputs of phosphorus compounds has been much higher than of nitrogen compounds, as a result of which the ratio between dissolved inorganic nitrogen and phosphorus has increased considerably since 1990 in some parts of the Wadden Sea, especially in the low salinity parts (10 psu) of the estuaries. Changes in N/P ratio may result in shifts in phytoplankton species composition and favor the development of toxic algae. So far, the changed N/P ratio has not resulted in significant changes in the occurrence of the nuisance algae *Phaeocystis* in the Marsdiep where the duration of blooms is still long. The intensity of *Phaeocystis* blooms at Norderney has considerably decreased in the period 1993-1996.

The abundance of potentially toxic species has remained low in the first half of the 1990s.

Zooplankton

Zooplankton forms an important link in the trophic structure of coastal ecosystems by making part of the primary production available to higher trophic levels. As a result of grazing, the zooplankton may also be able to control phytoplankton at low levels

It has been shown from enclosure experiments that many substances reduce copepod production thereby reducing the grazing pressure upon the phytoplankton. The toxic effect of, *e.g.,* tributyltin (TBT) reduced copepod growth and caused a shift in zooplankton species thereby diminishing the proportion of phytoplankton being grazed. This effect may have important consequences for eutrophication phenomena and the amount of production being passed on to higher trophic levels, *e.g.* fish.

Macrozoobenthos

The results of long-term monitoring programs on the macrozoobenthos of the tidal flats show large fluctuations in biomass between years. Much of the inter-annual fluctuation is caused by the group of bivalves within the Tidal Area. There does not seem to be a direct link between eutrophication and benthic biomass. In the western part of the Dutch Wadden Sea, benthic biomass has increased at the same time that nutrient levels have increased. In other areas, benthic biomass has

always been on such high levels. The recent decrease in eutrophication has not been followed by a decrease in benthic biomass or production. Climatic conditions, especially ice-winters, are probably the most determining factors in zoobenthos development, especially in bivalves. Macrozoobenthos biomass in the Offshore Area off Norderney has shown a significant increase since 1988 which wasattributed to the synergistic effect of mild meteorological conditions in winter.

Macroalgae and anoxic Sediment

Macroalgal coverage, which had increased since 1989, has decreased in the second half of the 1990s. The decrease could not be attributed solely to changes in eutrophication. Other factors exerting influence are hydrodynamics, climate, grazing and turbidity.

The burial of macroalgae has been identified as the main cause for the anoxic spots in the sediment of the East Frisian Wadden Sea (black spots). The large areas with anoxic sediment surface, which occurred in the spring of 1996 in the same area, had most probably been caused by a coincidence of hydrodynamic, meteorological and biological phenomena of which also a few cases from the past are known. High mortality rates of benthic organisms and a large amount of planktonic material, together with a sudden rise in temperature, exceeded the aerobic remineralization capacity of the benthic system and caused mass mortality of benthic animals. The question remains whether the East Frisian Wadden Sea has a more than average sensitivity for large amounts of organic material and whether the event must be judged as a sign of an exceeding of the benthic remineralization capacity in general. It is, furthermore, unclear which role local inputs of nutrients have played.

6.2.2 Hazardous Substances

Riverine Inputs

The Elbe is, by far, the major source of hazardous substances inputs to the Wadden Sea, mainly caused by the relatively large flow. The Elbe inputs of heavy metals (cadmium, copper, mercury, zinc, lead), lindane and PCBs decreased significantly between 1985 and 1996.

The Weser is, after the Elbe and Lake IJssel, the third most important source of freshwater input to the Wadden Sea. The Weser loads of mercury, lead and PCBs, however, are as high as the Elbe loads. For lead, there has even been a significant increase in input since the beginning of the 1990s.

For cadmium loads of the Ems and lindane inputs from Lake IJssel, significant reductions have occurred.

Concentrations in sediment, blue mussel and bird eggs

Sediment

Generally, over the last ten years, heavy metal concentrations in sediment have significantly decreased. The present range of metal levels in Wadden Sea sediments shows that the Danish and Schleswig-Holstein Wadden Sea is generally close to background levels. The Dutch and Niedersachsen Wadden Sea show, locally, enrichment of metals, especially cadmium and mercury, and, to a lesser extent, lead.

All investigated metals are within the range of provisional OSPAR ecotoxicological assessment criteria (EAC) for sediment.

PCBs in sediment show a more or less strong downward development and present levels are within the provisional OSPAR EAC.

HCB levels in sediments of the Ems estuary are up to a factor 6 higher than the agreed background range.

Blue Mussel

In blue mussel, metal concentrations show significant reductions between 1985 and 1996. This is the case for the Niedersachsen area N3 for copper and lead, and in the Elbe estuary for cadmium, mercury and possibly zinc, although the latter is actively regulated by blue mussel and, consequently, difficult to assess. Copper, mercury and zinc decreased significantly in mussels in the Halligen area (SH3). With the exception of zinc, which is within background range, metal concentrations in mussel are up to two times higher and mercury up to four times higher than the upper value of the OSPAR background range.

Generally, PCB levels in mussel are decreasing with the exception of in Ems-Dollard and Elbe estuaries where levels are very variable, possibly increasing recently, and, on average, two to three times higher than in other parts of the Wadden Sea.

HCB levels in mussel of the Elbe estuary are more than 20-fold the levels in other parts of the Wadden Sea. In the Ems estuary HCB levels in mussel are about twice the prevalent Wadden Sea level.

Bird eggs

Mercury levels in eggs of oystercatcher and common tern significantly decreased in the past decade in the western Dutch Wadden Sea, the Elbe estuary and the southern part of the Schleswig-Holstein Wadden Sea. In the Ems-Dollard, the Nie-

dersachsen and northern Schleswig-Holstein areas, there was no decrease but levels are still four to eight times lower here than in the Elbe,

PCBs and organochlorine pesticides in bird eggs showed a decrease in all investigated areas. In the Elbe estuary common tern eggs contain 2 - 3 times more PCBs than other investigated Wadden Sea areas.

Hexachlorobenzene (HCB) is decreasing in the bird eggs in the monitored areas (western Dutch Wadden Sea up to northern Schleswig-Holstein Wadden Sea). However, in 1996 the Elbe estuary HCB levels in common tern eggs were 20 - 40 times and oystercatcher eggs up to 4 times higher than the respective concentrations in the other investigated areas.

Pesticides and TBT

Most pesticides are not part of routine monitoring programs. Surveys in the Dutch and German coastal waters have revealed that many pesticides are present in high concentrations. Effects of pesticides on phytoplankton and zooplankton could be detected in research projects. Herbicides interfere with phytoplankton photosynthesis. Certain pesticides hamper zooplankton grazing. Pesticides may also be a factor in the decline of sublittoral eelgrass.

TBT concentrations in sediment exceed the OSPAR ecotoxicological assessment criterion over 1000-fold, even in the open Wadden Sea. TBT is toxic in very low concentrations, especially for whelks (*Nucella lapillus, Buccinium undatum*). Also, the blue mussel is sensitive to TBT but it is unclear whether TBT has played a role in the decline of littoral mussel beds.

6.2.3 Oil

Beached Bird Surveys (BBS) are suitable to show the specific risk of groups of birds to become oil contaminated at sea and, furthermore, to provide information on temporal changes or spatial differences in the occurrence of (chronic) oil pollution at sea.

According to long-term BBSs in the North Sea area, oil rates along the Dutch and Danish coasts of the Wadden Sea are generally higher than along the German Wadden Sea coastline.

In The Netherlands, the results of BBSs over the past 30 years have shown consistent declines in oil rates in all areas, especially in the Dutch Wadden Sea, for all seasons and for virtually all species. The oil rates are, however, higher than in relatively clean areas such as around the Shetland Islands. The results of Dutch investigations have provided no evidence for a sudden improvement since MARPOL Annex I came into effect in 1983. The gradual implementation of MARPOL may only have contributed to the continuation of the declining trend.

In Denmark, the oil rates are only partly decreasing, due to the illegal tank washing procedures of ships in the Kattegat and Skagerrak after leaving the Baltic Sea, which is a Special Area according to MARPOL Annex I.

After a decline in the oil rates in Germany in the years 1988 to 1991 - which ran parallel to the period in which reception facilities were free of charge in all German harbors - the 1991/92 data show an increase. A possible explanation is an increased illegal dumping of oil after the gradual phasing out of the free of charge disposal in 1991.

The results of chemical analysis of oil from polluted feathers suggest that mainly fuel residues from shipping are responsible for the pollution along the Danish-German-Dutch Wadden Sea and North Sea coasts.

6.2.4 Evaluation of the Eutrophication Target

Target

A Wadden Sea which can be regarded as a eutrophication non-problem area

The concept of the eutrophication problem and non-problem-areas was developed in the framework of the OSPAR Convention. In a so-called Common Procedure, the OSPAR Convention Area will be divided into eutrophication problem areas, non-problem areas and potential problem areas. According to the Statement of the OSPAR Ministerial Meeting (Sintra Statement) of 1998, this procedure will be finalized in 2003 after which additional programs and measures will be adopted necessary to ensure, by the year 2010, 'a healthy marine environment in which eutrophication, due to anthropogenic inputs, does not occur'.

Whether or not high nutrient loads will lead to eutrophication problems is, to an important degree, dependent upon regional hydrographical circumstances. Therefore, the development of criteria will be done on a regional basis. For the Wadden Sea region, specific criteria are presently being elaborated in a trilateral project. Because these criteria are not yet available, a full evaluation of the Target is currently not possible. However, on the basis of the above assessment, some conclusions can be drawn.

Conclusions

Phosphate loads and concentrations have decreased in the past ten years.

So far, this has 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.

Moreover, because nitrate loads and concentrations show no consistent decline, the ratio between nitrate and phosphate has increased. So far, this has not caused a notable increase in the proliferation of toxic algae.

With regard to undesired eutrophication effects, it must, therefore, be concluded that the target has not yet been reached.

6.2.5 Eutrophication: Recommendations for management

It is recommended to continue to implement current policies in the framework of the OSPAR Convention, The North Sea Conferences and the EU Nitrate and Municipal Wastewater Directives, especially with regard to nitrogen compounds.

6.2.6 Eutrophication: Recommendations for monitoring and research

There is increasing evidence of the important role of the adjacent North Sea in primary production, which is transported into the Wadden Sea. Monitoring in the Offshore Zone will, therefore, be essential for an evaluation of the eutrophication status of the Wadden Sea.

In marine areas with a relatively large tidal flat area, the remineralization efflux of nutrients from the sediments to the water causes a continuous build-up of nutrients in the water column throughout the winter period resulting in a large variation in nutrient concentration at the same salinity, but different geographical locations. As a consequence, the monitoring frequency should be increased during the period February and March and a good coverage of the entire salinity and/or geographical (inner to outer Wadden Sea) gradient must be guaranteed. The present layout of the national program-contributions to the TMAP cannot provide this guarantee for most Wadden Sea countries.

It is, furthermore, recommended to add zooplankton monitoring (community structure, grazing rates) to the phytoplankton monitoring program, to be able to evaluate interactions between both groups in response to environmental changes from either natural or anthropogenic origin.

More research is needed to solve the question whether the impact of mussel beds on the yearly primary production is positive or negative.

6.2.7 Evaluation of the Natural Micropollutants Target

Target

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

Micropollutants are substances which occur naturally in the environment. As a result of human activities, the concentrations of many of these substances have increased to levels that are, or could become, harmful. Amongst these substances are heavy metals such as mercury, cadmium and lead, and Polycyclic Aromatic Hydrocarbons (PAHs).

There have been several attempts to infer background concentrations of natural micropollutants, using, amongst others, sediment cores and estimates of natural riverine loads. In 1997, the Oslo and Paris Commissions adopted a set of background concentrations to be used as assessment tools. It is stressed that the OSPAR values are not Wadden Sea specific. The evaluation of the Target has been carried out on the basis of several estimates of the background values.

Heavy metals and PAHs in water are not part of monitoring programs because of the high variability. It is assumed that the quality of sediment is a reflection of the water quality.

6.2.8 Natural micropollutants: Recommendations for management

It is recommended to continue to implement current policies for the reduction of inputs of natural micropollutants, especially in view of the still elevated levels in biota.

6.2.9 Natural micropollutants: Recommendations for research and monitoring

A prerequisite for a proper evaluation of the Target is the availability of common, Wadden Sea specific, background values for mussel and sediment. It is recommended that such values be derived on the basis of a literature study, supplemented with field studies of sediment historical records.

With regard to oil pollution, it is recommended to make the analysis of oil from feathers of oiled birds part of the regular beached bird survey.

Conclusions

The loads of heavy metals from the Elbe, the major source of inputs to the Wadden Sea, have decreased significantly in the period 1985–1996.

Also, concentrations of metals in sediment have decreased and are approaching background levels. An exception is mercury for which levels are three to ten times higher than background levels.

The concentrations of all investigated heavy metals concentrations in sediment are lower than the provisional OSPAR ecotoxicological assessment criteria.

Concentrations of heavy metals in blue mussels generally show significant reductions in areas with previously high pollution levels. Zinc concentrations are within background range. Lead, copper and cadmium concentrations are up to two times, mercury up to six times higher than the upper value of the OSPAR background range.

Mercury levels in bird eggs have significantly decreased in the Elbe estuary but averaged levels in 1996 in common tern were still three to five times higher than in other regions.

PAH levels are within the range of proposed background levels and well below the ecotoxicological assessment criteria.

6.2.10 Evaluation of the Man-made Substances Target

Target

Concentrations of Man-made Substances as resulting from zero discharges

The occurrence in the environment of man-made substances, or xenobiotics, is the result of human activities, most notably, the production and application of substances such as PCBs, and synthetic pesticides.

The ultimate policy goal for xenobiotics is to have zero concentration in the environment. In practice, this would be almost impossible to achieve, even if all inputs would be zero. The reason is that large amounts of xenobiotics have already been introduced into the environment and, in many cases, their breakdown is a very slow process.

The evaluation of this Target is done on the basis of developments in inputs and concentrations. An indication of the potential danger of xenobiotics present in the Wadden Sea ecosystem is possible through the application of Ecotoxicological Assessment Criteria.

6.2.11 Xenobiotics: Recommendations for management

Of the different categories of pollutants, xenobiotics must be judged as the one that may be most dangerous to the ecosystem. It is recommended to intensify relevant policies for the reduction of the application of pesticides and other xenobiotic compounds in the framework of OSPAR, the North Sea Conferences and the EU.

6.2.12 Xenobiotics: Recommendations for monitoring and research

The present data on TBT urge for a concerted investigation of all Wadden Sea areas, on the basis of comparable analytical methods.
It is recommended to carry out a comprehensive evaluation of the situation regarding distribution and fate of pesticides, and other (potentially) dangerous substances, which are not part of regular monitoring programs.

Conclusions

Inputs of PCBs from the Elbe have decreased significantly between 1985 and 1996. Lindane inputs significantly decreased for most riverine sources.

Concentrations of PCBs in sediment show a steady decrease and organochlorine pesticides in bird eggs decreased in all investigated areas. PCBs in sediments in investigated Wadden Sea areas are within the OSPAR provisional ecotoxicological criterion range. The maximum of the firm ecotoxicological criterion for mussel, however, is exceeded with a factor of 3 in the Elbe estuary.

Hexachlorobenzene levels in eggs of the common tern in the Elbe estuary are up to 40-fold the prevalent Wadden Sea level.

The concentration of lindane in water in all estuaries is within the provisional OSPAR ecotoxicological assessment criterion range.

In several surveys, relatively high concentrations of xenobiotics have been detected. There is increasing evidence that certain pesticides hamper the grazing ability of zooplankton. Pesticides of the herbicide type interfere with the photosynthesis of phytoplankton. Pesticides may be a factor in the decline of littoral eelgrass.

TBT is highly toxic for several marine organism, amongst others whelks (Nucella lapillus, Buccinium undatum) and zooplankton species Levels in sediment have been shown to exceed the provisional OSPAR ecotoxicological assessment criterion up to a factor of 1000, even in the open Wadden Sea

6.3 Salt Marshes

The habitat type Salt Marshes includes all mainland and island salt marshes, including the pioneer zone. Also, the brackish marshes in the estuaries are considered part of this habitat type.

Generally, a differentiation is made between island salt marshes, mainland salt marshes and halligen salt marshes. There are three sub-categories of mainland salt marshes, namely the actual mainland salt marshes, summer polders and estuarine marshes.

Several factors have an impact on size, structure and biota of salt marshes. The major erosion, drainage, grazing and sea level rise.

6.3.1 Drainage and erosion

At present, most of the island salt marshes, and those along the peninsulas Skallingen and Eiderstedt, have a natural drainage structure, a system of creeks which has developed without human interference.

Most of the present mainland salt marshes developed in front of the dikes with the aid of sediment trapping techniques. In most of these artificial salt marshes, the drainage channels are being maintained for agricultural and/or coastal defense purposes.

Comprehensive experimental work has shown that it is possible to improve the naturalness of salt marshes without compromising their stability by the reduction of drainage channels and a cessation of systematic drainage in the salt marshes and the accretion zone.

The salt marshes are, in most cases, protected by brushwood groynes and, in some cases, by hard substrate. The protection of mainland salt marsh edges against erosion will, in most cases, remain necessary. Brushwood groynes are amongst the best environmental techniques for this purpose.

Sea level rise and bottom subsidence resulting from gas extraction have, according to Dutch research work, not yet caused an increased erosion of salt marshes. The accretion has been able to compensate for the combined effects of sea level rise and bottom subsidence. The vegetation has proven to be a major factor in the trapping of fine sediments. A prerequisite for accretion is the availability of sufficient fine-grained sediment. It has been postulated (see section 6.4) that the present hydrological situation in the Wadden Sea is not favorable for the sedimentation of fine-grained material.

6.3.2 Grazing

Several pilot projects have made clear that grazing is not necessary to protect salt marshes against erosion. Intensive grazing causes a loss of natural habitat structure which, amongst others, reduces the suitability as a breeding area. Heavy grazing may even result in a reduced soil stability of salt marshes.

A reduction of heavy grazing pressure by domestic animals can result in a more differentiated vegetation pattern. Much has already been achieved in reducing grazing pressure in salt marshes. In Schleswig-Holstein, a reduction from more than 95% intensively grazed foreland salt marshes to about 50% occurred in the period 1989-1995. In Niedersachsen, 60% of the salt marshes are currently ungrazed. There is an important difference in emphasis of salt marsh policies in The Netherlands and Germany. Whereas Dutch salt marsh management is directed towards achieving a diverse vegetation structure through a differentiated grazing pattern, the German management aims at achieving a more natural distribution and development of flora and fauna in relation to the geomorphological structure of the habitat by increasing the area of non-grazed salt marshes.

In Denmark there is, so far, no policy on grazing, but the Wadden Sea Plan will enforce Denmark to reconsider the strategy and management for grazing in salt marshes.

The reduction of active drainage, discussed in 6.3.1, will increase the naturalness of the vegetation and consequently the related fauna.

6.3.3 Evaluation of the Salt Marshes Targets

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 surface is not reduced

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

These three categories of Targets can best be evaluated in combination because they are interrelated.

The first option to increase the area of natural salt marsh is by means of natural accretion. Mainly,

as a result of the shortening of the main dikes for coastal protection and land reclamation purposes, there are few locations left along the mainland coast where a net sedimentation without the aid of brushwood groynes and other sediment trapping techniques takes place.

A second option is to reduce human interference in existing natural salt marshes, for example, by reducing grazing pressure where it is considered too high by reducing artificial drainage.

The outbankment of summer polders, as far as possible from a coastal protection point of view, is a third possibility. Reclamations in the past for agricultural purposes have led to a net reduction of the area of theoretically possible salt marshes. A secondary effect has been a reduction in the number of fresh-salt transitions. Through the outbankment of summer polders, new semi-natural salt marshes could be created which would also help to stabilize the total salt marsh area. Also, new fresh-salt transition zones could be created.

A trilateral working group is presently investigating the possible advantage of this option for the sediment balance of the Tidal Area. (see also Section 6.4).

6.3.4 Salt Marshes: Recommendations for management

In order to get a better overview of salt marsh policies, it is recommended that all partners in the trilateral cooperation prepare salt marsh policy plans, if they have not yet done so. The plans should contain the main principles and aims of salt marsh policies and management with regard to grazing, drainage, coastal protection, tourism and recreation, hunting and agriculture.

The possibilities for outbanking summer polders should be investigated more thoroughly and consistently.

All aspects of salt marshes should be included in coastal protection and nature protection policies, *i.e.* also their possible relevance for the sediment budget of the Wadden Sea and their possible role as areas with natural fresh-salt transitions.

6.3.5 Salt Marshes: Recommendations for monitoring and research

In 1986, the last comprehensive inventory of the situation of the Wadden Sea salt marshes with regard to surface area, management, drainage, grazing intensity and protection status, was carried out (Kempf *et al.*, 1986). It is recommended to initiate a new survey on the basis of harmonized quality criteria.

Monitoring of sedimentation patterns in the pioneer zone is a prerequisite for the evaluation of the effects of sea level rise and the role of salt marshes in the Wadden Sea sediment budget.

Conclusions

Much has been achieved in the past ten years with regard to improving the natural situation in salt marshes by the reduction, or phasing out, of grazing and artificial drainage, but there are differences in policies among the Wadden Sea countries. In The Netherlands, the goal is to achieve a diverse vegetation structure through differentiated grazing and the reduction of heavy grazing. In the German National Parks, the main aim is to gain a more natural distribution and development of flora and fauna in relation to local biotic and abiotic conditions by increasing the non-grazed area and reducing artificial drainage.

A precise comparison of the situation regarding the natural situation of salt marshes in the different parts of the Wadden Sea is presently not possible because of a lack of actual data and of common criteria.

The outbanking of summer polders has, so far, only been applied in the Dutch Wadden Sea. This practice not only increases the salt marsh area, but could also be favorable for creating new fresh-salt transitions and for maintaining the sediment balance of the Tidal Area.

The erosion of salt marshes does not yet seem to have increased as a result of sea level rise, bottom subsidence and higher wave energy, but a close monitoring of sedimentation patterns remains necessary.

6.4 Tidal Area

The Tidal Area covers all tidal flats (the littoral) and subtidal areas (the sublittoral). The border to the North Sea side is determined by an artificial line between the tips of the islands. The borders to the estuaries are determined by the average 10 ‰ isohaline at high water in the winter situation.

In this Section, the situation in the Tidal Area will be evaluated for three interrelated aspects, namely hydrology/geomorphology, climate and biology.

6.4.1 Hydrology/geomorphology

The Tidal Area and Offshore Zone can, from the perspective of hydrology and sedimentology, be considered as one system. Sea level rise causes an increased net sand import into the Wadden Sea. The sand originates from the Offshore Zone as far as the 20-m isobath. This, in turn, will cause a landward migration of the islands. When the islands coasts are fixed by hard constructions or beach nourishments, the foreshore will show a gradual steepening.

This erosion-sedimentation pattern causes the barrier islands to move into the direction of the mainland. The straightening of the shoreline and the disappearance of many sheltered bays, together with the fact that large areas have been embanked and, consequently, the area between the islands and the mainland has become smaller, have, worsened the conditions for sedimentation of fine-grained particles.

It has been hypothesized that disturbance of benthic communities by shellfish fisheries may lead to higher sediment mobility and erosion and, consequently, unfavorable conditions for the settling of fine sediment.

6.4.2 Climate change

Human activities have increased the concentrations of the so-called greenhouse gasses in the atmosphere. In 1995 the International Panel on Climate Change (IPCC) had concluded that "the balance of evidence suggests that there is a discernable human influence on climate". A global temperature rise of 1-3.5 °C by 2100 is predicted. This may, amongst others, lead to sea level rise and changes in wind conditions. In the 1993 QSR, the acceleration of the increase in Mean High Water level (MHW) and Mean Tidal Range (MTR) in the last decades was attributed to climatic changes. More recent analyses point to long-term cyclic processes. The increase in intensity and frequency of storm surges as a result of climatic changes, suggested in various publications, could not be substantiated in recent analyses of long-time series.

In the 1990s, a more comprehensive picture has emerged about the possible consequences of accelerated sea level rise and bottom subsidence for the Wadden Sea. Both sea level rise and bottom subsidence cause an increased transport of sediment into the Wadden Sea. This presupposes, however, an adequate supply of sediment from the Offshore Zone. Whether or not tidal flats will decrease in size depends on many factors, amongst which are the speed of sea level rise and/or bottom subsidence, the availability of sediment and the possibilities for sedimentation.

An average long-term increase in temperature, in particular winter temperature, could exert its influence mainly through the macrozoobenthos. On the one hand, macrozoobenthic species are the primary consumers of phytoplankton, microphytobenthos and detritus; on the other hand, they are the main food source of crustaceans, fish, and bird species. Generally, higher winter temperatures would favor macrozoobenthic biomass and, consequently, its predator species.

6.4.3 Biota

Chapter 5 contains comprehensive descriptions of the species, species groups and communities of the Tidal Area. In this section, the main findings with regard to fish, blue mussel beds, *Sabellaria*, oysters and eelgrass beds are evaluated. In 6.2, the relations between eutrophication and phytoplankton, macroalgae, macrozoobenthos and zooplankton are discussed. Section 6.4.2 addresses effects of changes in climate on macrozoobenthos.

Birds and marine mammals are addressed in 6.8 and 6.9, respectively.

Blue mussel beds

Recent studies have confirmed that blue mussel beds play an important role in the ecology of the Wadden Sea, both in sediment dynamics, nutrient dynamics, biodiversity and as food source for birds.

The area covered by littoral mussel beds is still very small. In The Netherlands, in 1998, only a few percent of the Dutch reference value of 5,000 ha was present and consisted of young immature beds which are vulnerable to winter storms. No significant recovery has occurred in the past three years, not even in the part that was closed for mussel and cockle fisheries. In Niedersachsen, the area of littoral mussel beds had decreased from 5,000 ha in

1975 to some 790 ha at the beginning of 1996. The reduction in biomass is even more dramatic. From 1996-1997, a moderate recovery to 1,200-1,400 ha was observed. In Schleswig-Holstein, the area of littoral beds has been stable since fishery has been restricted to the sublittoral areas but many beds are still immature and vulnerable. In Denmark, mussel beds, both in areas closed for fisheries and areas with regulated fishery, developed between 1995 and 1996 after a decline between 1991 and 1995. Ice coverage is the most important regulating factor for the development of mussel beds in the Danish Wadden Sea.

Because new beds seem to settle in places where mature beds used to occur, protection of developing beds is a precondition for recovery of mussel beds.

Oyster beds

The native oyster (*Ostrea edulis*), which was once widespread in the Wadden Sea, became extinct some 50 years ago. Since the beginning of the 1990s *O. edulis* has been found again in small numbers in the Schleswig-Holstein Wadden Sea. It is unclear whether re-establishment will occur over larger areas, also because former sites are now occupied by mussel beds.

The Pacific oyster (*Crassostrea gigas*) was first reported in the Wadden Sea at the beginning of the 1980s. It is likely that this introduced species will expand in the coming years.

Sabellaria

The reef building polychaete *Sabellaria* sp. is probably still occurring on two locations in the German Wadden Sea. Extensive reefs can be considered extinct, although it is not clear whether they have ever occurred in the Dutch part of the Wadden Sea. In Germany, most of the reefs have disappeared possibly because of fishing activities with sediment disturbing trawls and dredges. Regeneration may be possible in areas which are closed for fishery with bottom gear. It is not known whether these reefs will redevelop if fishery is stopped.

Sabellaria larvae are strongly stimulated to metamorphose and settle by cement excretions of adult or newly settled young *Sabellaria*. The larvae are also able to detect biochemically, old worm tubes which have been built by the same species. Therefore, several potential settling grounds for a spontaneous regeneration of this characteristic type of Wadden Sea biotope exist.

Eelgrass

In the past, sublittoral populations of eelgrass (*Zostera marina*) covered vast areas in the entire Wadden Sea. After an epidemic disease, probably caused by the protozoan *Labyrinthula macrocystis*, in the early 1930s, the sublittoral eelgrass beds completely disappeared and never reestablished. In the littoral, a severe decline of the area covered by eelgrass has been observed over the last decades. In the Dutch Wadden Sea, only a few scattered seagrass stands have survived until today. Recently, a local re-establishment of another eelgrass species, *Zostera noltii,* has been observed.

The causes of the decline are still unknown. Possible factors are eutrophication, phytotoxic pollutants like herbicides, increased turbidity, macroalgal blooms and the reduction of fresh water inputs due to man-made constructions.

Fish and shrimp

Systematic monitoring in the Dutch and German Wadden Sea is only done for demersal (bottom-dwelling) species in the gullies deeper than 2 m and no information is present for the tidal and sublittoral flats nor for pelagic (non-bottom-dwelling) species.

In the Dutch Wadden Sea, there seems to be a trend towards lower abundance levels of brown shrimp, juvenile sole, juvenile plaice, juvenile eel, viviparous blenny and bull rout. For flounder, five-bearded rockling and hooknose, no clear trend was found in the Dutch Wadden Sea. Whether the observed decrease of juvenile plaice, viviparous blenny and bull rout in the period 1978-1996 is a sign of fundamental changes in the complex ecosystem of the Wadden Sea, can only be judged on the basis of more information than the scarce fish abundance data presented here.

Further improvements in the physical conditions of the rivers seem to be the most important factor ensuring a satisfactory reproductive stock of salmonid fish species.

6.4.4 Evaluation of the Tidal Area Targets natural dynamics and geomorphology

Targets

A natural dynamic situation in the Tidal Area

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

These Targets aim at reducing the anthropogenic impact on physical and biological processes in the

Tidal Area. These processes are, to an important degree, determined by fixed coastal protection structures. Also, dredging, fisheries, sand extraction and gas extraction affect hydrological, geomorphological and biological processes.

A full implementation of the Targets will probably not be possible because of the present anthropogenic boundary conditions of which the dikes are the most pertinent.

The dynamics and geomorphological and biological processes in the Tidal Area have been strongly influenced by past and present human interference. As a result the natural capacity of the Tidal Area to cope with sea level rise and the possibilities for the settling of fine grained material may have decreased.

The implementation of the Targets requires an integrated approach taking into consideration the effects of accelerated sea level rise and the combined effects of all human impacts in both the Tidal Area, the Salt Marshes and the Offshore Zone. Also, the role of structure building biological components in the Tidal Area, *i.e.* mussel and oyster beds, seagrass fields and *Sabellaria* reefs, in hydrological and sedimentological processes must be taken into account.

Conclusions

As a result of human interference, (fixed coastal constructions, fisheries, dredging, sand extraction and gas extraction) the ability of the system to compensate for sea level rise may have decreased. Also, the settling conditions for fine-grained sediment may have become worse.

The implementation of the Targets should be based on an integrated assessment of all interfering human activities under different sea level rise scenarios. It is essential that the Tidal Area, the Salt Marshes and the Offshore Zone are considered as one system when dealing with hydrology and geomorphology.

6.4.5 Evaluation of the Targets for mussel beds, *Sabellaria* reefs and *Zostera* fields

Targets

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

Blue mussel beds and seagrass meadows are important communities in the Tidal Area. They are a habitat for many other species and influence hydrodynamic processes in such a way that current velocities are reduced and mud and sand are trapped. The *Sabellaria* worm is the only reef building species in the Tidal Area.

The areal extension of mature mussel beds and seagrass meadows has decreased considerably in the past decades. *Sabellaria* reefs are almost extinct.

The evaluation of the Targets is hindered by a lack of precise data from the past and uncertainties as to the cause of the decline. As possible causes changes in climate, disease, pollution and mechanical disturbance have been suggested. There are clear indications that fisheries with bottom gear interfere with the recovery of these communities

Conclusions

The Target of an increased area and a more natural development of natural mussel beds, eelgrass meadows and *Sabellaria* reefs has not been reached. The decline in number and size of mature beds of the blue mussel and seagrass meadows has continued in this decade.

The decrease of these structure-building communities may also influence hydrology and sedimentology in the Tidal Area.

6.4.6 The Tidal Area: Recommendations for management

Our present understanding of the hydrological and geomorphological processes and their interactions, together with the role of mussel beds and seagrass meadows, is still insufficient to warrant reliable prognoses but several management implications may be considered, such as:

- outbanking of former salt marshes, wherever feasible, in order to maintain the sediment balance and a high fine particle content;
- reduction or cessation of the extraction of sand, gravel and shells in the channels because this may result in sediment losses on adjacent tidal flats;
- cessation of fishery on shellfish in the littoral because this may initiate irreversible changes in the sediment and the biota and hamper recovery;
- the further designation of undisturbed areas. There may be important differences in the interactions and the effects of human interference

between different tidal basins in the Wadden Sea. Management should, therefore, be based upon the Tidal Basin approach (See also 6.4.7).

Areas where old mussel beds used to occur or where remnants are left, provide the best chances for the settlement of new beds. Management should, therefore, focus on the protection of such sites.

Areas closed for mussel and cockle fisheries may also serve to protect littoral *Zostera* meadows.

Conservation management of *Sabellaria* must be directed towards the protection of both living and dead reefs because settlement of larvae is stimulated by the presence of these structures.

6.4.7 The Tidal Area: Recommendations for monitoring and research

Geomorphology

There is an urgent need for further research on the interactions between sediment composition, disturbances and subsequent biotic developments.

Reference areas

It is essential that the decision of the Esbjerg Conference (1991) to designate 'sufficiently large areas, spread evenly over the Wadden Sea, where all exploitation and disturbing activites are banned and which can serve as reference areas for scientific purposes' (ED, § 33.3), be implemented.

Reference areas meet 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 from the Trilateral Monitoring and Assessment Program (TMAP) depends 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.

According to the Ministerial Declaration of the TCG in Esbjerg, areas serving as reference areas should

- have a minimum size;
- comprise an ecologically coherent unit;
- cover the whole variety of characteristic habitats;
- be spread evenly over the Wadden Sea;
- be free of exploitation and disturbances.

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.

Fish

Systematic monitoring in the Dutch and German Wadden Sea is only done for bottom dwelling species in the gullies deeper than 2 m and no information is present for the tidal and sublittoral flats as well as for non-bottom dwelling species.

More information is needed to judge whether the decrease of juvenile plaice, viviparous blenny and bull rout has its cause in fundamental changes in the ecosystem.

The assessment of changes in fish populations would be very much improved if data from fished and non-fished reference areas could be compared.

Mussel beds

Several problems arise when describing the spatial extent of mussel beds. The main problem is that there is no clear definition of what different investigators mean by a mussel bed. When calculating the surface area of the bed there is a certain amount of variation between investigators. For future monitoring, it is essential to develop a protocol so that different investigations can be better compared.

There is hardly information about the development of older stable mussel beds in the sublittoral. It is therefore recommended to address the situation with regard to sublittoral mussel beds in the next QSR.

Oyster

Monitoring of the introduced oyster *Crassostrea gigas* is necessary to evaluate the effects on the native biota.

Sabellaria

Monitoring of *Sabellaria* should be done primarily in areas where sabellarian reefs have been recently observed, so as to get more information about the population. Pilot studies will be necessary before *Sabellaria* can be included in the TMAP.

Eelgrass

It is necessary to reveal the causes of the decrease and monitor the further development of the eelgrass population.

6.5 Beaches and Dunes

Beaches and dunes include beaches, primary (white) dunes, beach plains, primary dune valleys, secondary dunes and heathland behind the dunes.

Beaches and dunes develop through landward sand transport by wind and water and subsequent sediment sorting by currents. Thus, especially beaches and young dunes are characteristic features of the dynamic of the Wadden Sea ecosystem.

As a result of anthropogenic influences, especially agriculture, coastal protection and recreation and tourism, natural and undisturbed beach and dune areas have become rare.

6.5.1 Natural Dynamics

Coastal protection limits the dynamic of sand transport and conservative measures preserve actual zoning patterns. Most of the older dunes are consolidated, partly covered by pine wood plantations. They are erosion free now without the natural renewal of secondary dune formation.

The percentage of white dunes may be used as an indicator of dune natural dynamics. A comparison of inhabited Dutch and German barrier islands shows that Vlieland, Terschelling, Schiermonnikoog, Baltrum, Mellum and Amrum have more than 20% white dunes, whereas the other islands have less than 20%. The difference may be explained by differences in management, but boundary conditions such as erosion patterns, tidal range, and size of the island are probably more important.

6.5.2 Natural Vegetation

The present dune vegetation is strongly anthropogenically determined. The major factor is the above-described stabilization by coastal protection measures as a result of which, the natural, early as well as the oldest successional stages, are underrepresented. An intensified geomorphological dune turnover will improve community patterns on the benefit of complete series without emphasis on older stages.

Past activities like grazing and turf cutting have caused an enrichment of early successional stages and prevented wood formation.

The dunes are affected directly by tourism mainly by trampling which causes destruction of sensitive dune vegetation. A more indirect effect of tourism is probably the increased groundwater extraction. Considerable effects on the community composition of wet dune valleys have been reported. The plantations of *Pinus sylvestris* also place a burden upon the available groundwater.

The rose species *Rosa rugosa* was originally brought to many of the islands for decorative purposes. This species, however, does not integrate in the local plant communities but superimposes by covering large areas.

6.5.3 Evaluation of the Targets natural dynamics and natural vegetation in dunes

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

There is limited information about the present natural status of dunes and beaches and even less about temporal developments. The percentage of white or primary dunes has been used as a first indication of the level of dynamics. Other relevant factors must, however, be taken into consideration for a more thorough evaluation. It concerns, in particular, the specific situation with regard to

Conclusions

The status of the dunes in the Wadden Sea Area has been, and still is, determined by conservative measures of coastal protection which preserve directly (planting of marram grass) or indirectly (building of sand dikes, groynes etc.) the zoning patterns. As a result, there is a relatively high percentage of intermediate stages and an underrepresentation of primary and oldest stages.

There are considerable differences in the percentage of primary dune area between the different barrier islands but, generally, it may be concluded that there is a considerable potential for implementation of the targets.

It is expected that an increase in natural dynamics will also lead to a more natural vegetation succession.

The vegetation in dune valleys can be negatively influenced by increased groundwater extraction.

erosion patterns and size of the island.

The status of the vegetation is directly dependent upon the geomorphological situation. An increase of natural dynamics of dunes and beaches will lead to a more natural vegetation succession.

6.5.4 Beaches and Dunes: Recommendations for management

An increase in natural dynamics in the dunes of most islands may be achieved by abandoning, reducing or modifying coastal protection maintenance works, depending upon local conditions, and as far as safety is not impaired.

In those areas where vegetation is impacted by a low groundwater table, the aim should be to reduce groundwater extraction.

The suppression of *Pinus* spp. and *Rosa rugosa* may be forced, as these species act as main competitors for autochthonous species.

6.5.5 Beaches and Dunes: Recommendations for monitoring and research

For a proper evaluation of the possibilities of implementing the Targets, it is necessary to carry out a detailed inventory into local factors relevant for dune management, in particular erosion-sedimentation patterns, exposure to storms and size of the island.

There must be full access to data about groundwater extraction, so as to be able to judge more precisely to what extent the vegetation is influenced by groundwater extraction.

The spreading of alien/introduced species has to be monitored in order to detect signs of strong displacement effects on the local flora and fauna.

6.6 Estuaries

Estuaries include the estuaries of the rivers with a natural water exchange with the Wadden Sea. On the landward side, estuaries are delimited by the mean-brackish-water line. On the seaward side, the border is the average 10‰ isohaline at high water in the winter situation.

6.6.1 Morphological Changes

Anthropogenic modifications of estuaries have been accompanied by changes and losses of habitats and ecological functions. In the last century, riparian forests, extensive marshes and semi-terrestrial areas bordering the rivers have been embanked for coastal protection and for agricultural purposes The diking of freshwater/brackish marshes and reeds and the subsequent drainage for agricultural use has destroyed areas of major importance for breeding and migratory birds. Another consequence has been the reduction of the natural retention function as these inundation areas have served as reservoir for water masses during storm surges.

The construction of tidal weirs and sluices has led to a lack of a natural salinity gradients. These constructions hinder, or prevent, the migration of invertebrates and fish species and hamper the tidal influence in the upper reaches of the estuaries. As a consequence, fish species like sturgeon, houting, salmon and trout are now extinct or, are in danger of extinction. Restoration of smooth gradients of salinity and tidal amplitude in small creeks along the Wadden Sea coast and in the estuaries would improve the conditions for long-term maintenance of endangered migrating species.

The morphology of the Elbe, Weser and Ems estuaries has been altered in order to optimize their function as shipping routes. Their depths have been, and still are, continuously adjusted to the increasing size of vessels. The canalization has resulted in a loss of littoral and shallow sublittoral areas and in an increase of the tidal range.

It is not expected that the effects of most of the above outlined impacts will be reduced in the near future. On the contrary, on the basis of ongoing projects a further impact on the natural dynamics will occur through deepening (Elbe, Weser) and the construction of a surge barrier (Ems). In The Netherlands, no tidal rivers have remained. Sluicing regimes will, however, be adapted to a more natural situation and it will be investigated to what extent salt-fresh transitions can be restored.

The Varde Å in Denmark and the Godelniederung on Föhr are the only natural estuaries in the Wadden Sea area. The banks of the Varde Å are used for intensive agriculture but, recently, an extensification scheme has been initiated.

6.6.2 Water Quality

Inputs by rivers are the main cause for elevated nutrient and contaminant concentrations in the Wadden Sea. The inputs of industrial and municipal waste water as well as land runoff from the riverine catchment areas are responsible for the high riverine loads of nutrients, heavy metals and organochlorines. Part of these substances is deposited in the estuaries by removal processes and may enter the estuarine food web. The concentrations of nearly all monitored pollutants have decreased significantly in the estuaries of Ems, Elbe and Eider. Nevertheless, some chemicals are still found in bird eggs in concentrations capable of impairing bird reproduction.

6.6.3 Evaluation of the Estuaries Target

Targets

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

Within the Wadden Sea Area, there are four estuaries which have been defined as such in the Wadden Sea Plan. In addition, the Godel on the island Föhr could be classified as an estuary.

The estuaries are very different in character ranging from rivers with high flows to streams such as the Godel. Also, human use in the estuaries varies greatly as well as the extent to which the rivers have been modified.

These differences are a complicating factor in the evaluation of the Target. Moreover, the Target refers to 'valuable parts' of rivers, a category which must be defined more precisely before evaluation is possible.

Conclusions

Only five estuaries have remained in the Wadden Sea area (Ems, Weser, Elbe, Godel, Varde Å). As a consequence, natural transitions of fresh and salt water hardly exist in the Wadden Sea Area.
The Varde Å and Godel are estuaries which have retained their natural character.

The Ems, Weser and Elbe and their tributaries have been modified considerably by diking 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 anticipated construction of a barrage in the Ems.

It must, therefore, be concluded that these estuaries are moving farther away from the Targets.

6.6.4 Estuaries: Recommendations for management

Further elaboration of the Target for estuaries is necessary, taking account of the special character of each estuary and specifying the notion 'valuable parts'.

The consequences of further impact due to further deepening, barriers and harbor extension should be evaluated very carefully, taking into account the historical deterioration of the estuaries and the uniqueness of each estuary. There are still possibilities to restore estuarine habitats that have been lost by diking. The first step could be an inventory of the most suitable sites for de-embankment.
Improvement of the physical conditions, such as restoration of smooth gradients of salinity and tidal amplitude in small creeks along the Wadden Sea coast and in the estuaries, would be beneficial for endangered migrating species, like salmonids.

6.6.5 Estuaries: Recommendations for Research and monitoring

Long-time data series of systematic monitoring only exist for hydrological and water quality parameters. Biological monitoring programs were set up a few years ago. They have to be maintained and intensified in order to evaluate the anthropogenic impact on community structures and ecological processes and to detect long-term changes.

6.7 The Offshore Zone

The Offshore Zone ranges from the 3 sea-mile line to an artificial line connecting the outer tips of the islands. The border between the Offshore Zone and the beaches on the islands is determined by the average low-tide water mark.

6.7.1 Geomorphology

The Offshore Zone, up to a depth of 20 m, forms one morphological system with the Tidal Area. This is best illustrated by the sand displacement between barrier islands: sand and silt are transported back and forth between the Tidal Area and the Offshore Zone. The Wadden Sea system which consists of tidal inlets, tidal basins, outer deltas and neighboring island coasts has a closed sand economy. The consequence of this dynamic equilibrium is that disturbances will be compensated until a new equilibrium is reached. Sea level rise and bottom subsidence both cause a deepening of the tidal basin resulting in an increased net sand import from the Offshore Zone. In the end, this sand originates from the North Sea side of the islands. Together with a net sedimentation on the mainland side, this results in a landward movement of the islands. However, most of the inhabited islands have been (partly) stabilized by fixed coastal defense works and. As a consequence, the foreshore of the islands may steepen. Ultimately, the tidal flat system may disappear because no sufficient sand can be delivered.

6.7.2 Biology

Also, biologically, the Wadden Sea and North Sea are intimately linked. Phytoplankton is transported from the Offshore Zone to the Wadden Sea proper and is remineralized there. The import of organic material from the Offshore Zone is one of the main causes of the 'food richness' of the Wadden Sea. Several shellfish, like the cockle and blue mussel may restock the Wadden Sea from deep water refuges in the North Sea after a severe winter has decimated the population of the exposed 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. Without the Wadden Sea, the stocks of such species would be greatly reduced.

Several groups of birds occur in internationally important numbers in the area. Sea ducks take advantage of the relatively shallow waters that hold rich banks of bivalve food species, particularly trough clams (*Spisula subtruncata* and *S. solida*). Spisula fishery affect the food availability for diving ducks in winter.

Local fish eaters like gulls and terns breeding at Wadden Sea islands, as well as autumn (gannet *Sula bassana*, great cormorant *Phalacrocorax carbo*, terns) and winter visitors (divers, auks) specifically seek out these waters that are so rich in small fish. In total, the coastal zone of the North Sea holds a specific seabirds assemblage in all seasons, and may be seen as a specific ecotope that is not found further inshore (Wadden Sea) or offshore (the open North Sea).

Discard and offal from fisheries in the coastal area have a considerable impact on the populations of gull species like herring gull *(Larus argentatus),* lesser black-backed gull *(Larus fuscus*) and great black-backed gull (*Larus marinus*).

The grey seal (*Halichoerus grypus*) and the common seal (*Phoca vitulina*) use both the Wadden Sea and the North Sea. In winter, when feeding conditions deteriorate for the seals in the Wadden Sea, they follow the fish into the North Sea in order to forage.

The harbour porpoise (*Phocoena phocoena)* is the most common cetacean species with many thousands present in the area. Highest densities have been calculated for the area off Sylt, Amrum and southern Rømø. This area has been identified as a breeding and nursing ground for this species.

6.7.3 Evaluation of the Offshore Zone Targets

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

From a geomorphological perspective, the Offshore Zone and the Tidal Area form one system. The Target regarding the natural morphology of the Offshore Zone can, therefore, only be evaluated in connection with the Targets for natural dynamics and geomorphological processes in the Tidal Area (see 6.4).

The Targets regarding birds and mammals are also addressed in 6.8 and 6.9.

Conclusions

Both from physical and biological perspectives, the Offshore Zone and Tidal Area are closely connected.

From a geomorphological point of view, the Offshore Zone and Tidal Area can be considered as one system.

The Offshore Zone is an important source of organic material for the Tidal Area.

It is also a food source and refuge for many invertebrate, fish and bird species and its role as breeding and nursing ground for the harbour porpoise has become more obvious in recent years.

6.7.4 The Offshore Zone: Recommendations for management

Because of the many interactions between Offshore Zone and Tidal Area, it is recommended that the management and protection of these two habitats be closely tuned. The evaluation of impacts in the Offshore Zone should also take into consideration effects in the Tidal Area and vice versa.

The removal of sand from the Offshore Zone should be limited as much as possible. Sand for nourishment purposes and other coastal protection activities should, preferably, be extracted from beyond the 20-m isobath.

Spisula fishery may affect food stocks that are essential for diving ducks in winter. Appropriate management is necessary to prevent negative effects on the bird populations.

Discards from fisheries in the coastal area should be reduced.

Considering the high densities of harbour porpoises in the coastal zone off Amrum and Sylt, it is recommended to designate a marine reserve in this area.

6.7.5 The Offshore Zone: Recommendations for monitoring

The interactions of Offshore Zone and Tidal Area also have consequences for monitoring.

Monitoring of primary production in the Offshore Zone is important for evaluating the eutrophication status of the Tidal Area (see also 6.2.4).

Bird numbers at sea, especially moulting sea ducks, are only poorly known. It is, therefore, recommended to improve monitoring of birds in the Offshore Zone.

A regular monitoring scheme for harbour porpoises in the coastal zone should be set up and become part of the TMAP.

Generally, studies are needed to elucidate the specific significance of the Offshore Zone within the Wadden Sea ecosystem. It is also recommended to start an inventory of the information needs regarding proper management, which may serve as a basis for the development of an adequate monitoring program in the offshore area. Such a monitoring program may include phytoplankton primary production, benthos, juvenile fish, moulting /foraging birds, and harbour porpoises.

6.8 Birds

6.8.1 Breeding Birds

The Wadden Sea is an important reproduction area for more than 30 species of breeding birds.

Over the last decades, the population of many of the bird species breeding in the Wadden Sea have significantly increased (common gull, *Larus canus*, arctic tern, *Sterna paradisaea*; lesser black-backed gull, *Larus fuscus*), some are stable (avocet, *Recurvirostra avocetta*; great ringed plover, *Haradrius hiaticula*; black-headed gull, *Larus ridibundus*) or have decreased (kentish plover, *Charadrius alexandrinus*; little tern, *Sterna albifrons*; ruff, *Philomachus pugnax*), some species have extended their distribution range (eurasian spoonbill, *Platalea leucorodia*; great cormorant, *Phalacrocorax carbo*) and, luckily, non have become extinct. The reason for the increase and decrease in population size and the factors threatening the populations are manifold. They range from the positive effects of conservation measures to global climate change.

Many breeding bird species are recovering from drastic declines in the past caused by persecution (*e.g.* hunting, egg collecting), recreation and pollution.

6.8.2 Migrating and Staging Birds

The Wadden Sea, including its tidal flats and salt marshes, constitutes one of the worlds most important wetlands for migratory waterbirds (ducks, geese, waders, gulls, terns and others) which breed in northwestern Europe, the western and central parts of Siberia, on Iceland, Greenland and the northeastern part of Canada. The Wadden Sea Area is of outstanding international importance as a staging, moulting and wintering area for at least 52 populations of 41 species using the East Atlantic Flyway, *e.g.* grey plover (*Pluvialis squatarola)*, siberian knot (*Calidris C. canutus*), dunlin (*Calidris A. alpina*).

High numbers of moulting ducks and geese, in particular shelduck (*Tadorna tadorna*) and common eider (*Somateria mollissima*), are present on the tidal flats every year. For the shelduck, the Wadden Sea is the only moulting area for the North European population.

Migratory birds, such as some waders, ducks and geese species also use rural areas on the islands and on the mainland behind the dikes during their stay in the Wadden Sea area. Meadows, pasture land and arable land are utilized by golden plover (*Pluvialis apricaria*), common lapwing (*Vanellus vanellus*) and also ruff (*Philomachus pugnax*) and whimbrel (*Numenius phaeopus*) as roosting sites, mainly in spring and autumn. Widgeon (*Anas penelope*), barnacle goose (*Branta leucopsis*) and, to a lesser extent, also brent goose (*Branta bernicla*) as herbivores, also use meadows and arable land as feeding areas during autumn and spring.

6.8.3 Factors affecting populations

The main factors determining the population sizes of birds are winter weather conditions, mussel and shrimp fisheries, hunting and other disturbing human activities, the availability of salt marshes and the availability of undisturbed beaches.

Fisheries

Effects of over-exploitation of mussel and cockle stocks on eider ducks and oystercatchers have been documented in Denmark and The Netherlands. Bycatch from shrimp fisheries has been an important factor in the increase of gull populations.

Salt marshes

The large embankments, which have been carried out in the last decades, have seriously reduced the size of salt marshes and, consequently, the availability of breeding sites for coastal waterbirds and feeding areas for geese and widgeon. Of the remaining salt marshes, those, which are intensively grazed, are less attractive as breeding sites for a number of species such as redshank or ducks.

The reduction in grazing of salt marshes in recent years, locally, resulted in increased breeding numbers for some species, *e.g.* redshank, but may have resulted in smaller numbers of geese and widgeon.

Beaches and dunes

Bird species breeding mainly in dune areas are, for example, common eider (*Somateria mollissima*), herring gull (*Larus argentatus*) and hen harrier (*Circus cyanus*). Great ringed plover (*Charadrius hiaticula*), kentish plover (*Charadrius alexandrinus*) and little tern (*Sterna albifrons*) build their nests on beaches, primary dunes and sandpits.

Natural beaches and primary dunes have not only become a rare commodity due to the decreased dynamics. In addition, the remaining primary habitat sites suffer from increased human disturbance, mainly from tourism and recreation. These areas are indispensable breeding areas for specialized, and still endangered, birds like the kentish plover and the little tern.

Human disturbance

Long-term effects of local disturbance on populations are difficult to assess. It has been observed, however, that moulting birds concentrate in areas which are the least subject to disturbance.

Hunting

Flight distances of brent goose and barnacle goose have decreased as a result of a reduction of hunting. Generally, a reduced hunting pressure will result in an increase in the condition of waterbirds.

Wind turbines

Areas behind the dikes are used by a large number of birds as high tide roosts. Wind turbines in these areas are avoided by birds as breeding and roosting areas. Wind turbines also interfere with migratory routes.

6.8.4 Evaluation of the Target 'Favorable conditions for birds'

Targets

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.**

Quantification and interpretation of the Targets

The quantification and interpretation of the Targets for birds has been extensively discussed within the trilateral bird expert groups. It was concluded that the general Target for birds applies to all habitat types in the Wadden Sea. Salt marshes and estuaries are of great importance to birds in the Wadden Sea as breeding areas, high tide roost sites and as feeding grounds. Therefore, the general Target for birds and its sub-targets should also be applied to 'Salt marshes' and 'Estuaries'.

The further quantification of the sub-Targets was not considered appropriate because of the the dynamic character of the Wadden Sea, the great variability of the ecosystem in time and space and the fact that little appropriate data are available to determine the 'natural' population parameters, such as the size of populations and natural breeding success.

With regard to the interpretation of the sub-Targets, several proposals were elaborated.

Food availability

When assessing the sub-Target 'favorable food availability' it should be borne in mind that anthropogenic influences and activities in the Wadden Sea not only cause negative effects (for example, competition with mussel fisheries in years with poor shellfish stocks), but also 'favor' some species due to an unnaturally increased food availability, for example by eutrophication or fishery discards.

Flight distance

'Flight distance' is the distance between a bird and a human disturbance factor at which the bird reacts to the given factor by fleeing. Though we do not know the 'natural' flight (escape) distances of birds in the Wadden Sea, the present flight distances are high, mainly because of hunting in the Wadden Sea and adjacent areas. This unnaturally high flight distance causes other human activities to work as disturbances as well, which would often not cause effects if the flight distances were smaller.

Breeding success

There are no appropriate long-term data on breeding success of the breeding bird species in the Wadden Sea that would allow to give a reference value for the natural breeding success.
A non-numerical criterion for evaluating the Target on breeding success is the following:
The breeding success should be so high that the reproduction rate balances the annual natural mortality, resulting in a population remaining stable at a natural size over a longer period of time without immigration from other breeding areas. Population changes due to natural changes should be taken into account in the assessment.

Roosting areas

To avoid energy loss, birds try to avoid unnecessary flights; *i.e.* they choose safe roosting sites which lie closest to their feeding areas. Therefore, undisturbed roosting sites should be distributed along the whole coastline and they should not lie far apart. Despite of the size of roosting sites, their number and distribution are essential.

It is not possible to quantify the minimum size of a given roosting site in ha. A non-numerical criterion for the size of an undisturbed roosting area could be that birds can roost there without being disturbed by human activities in the vicinity.

Moulting areas

High numbers of moulting ducks and geese, at the moment regarding shelducks and eiders, are present in the Wadden Sea every year. These birds

are flightless during moult and extremely susceptible to disturbances (flight distances up to some km!). Aside from food availability, the lack of disturbance is the primary factor allowing these birds to moult in a specific area. Several investigations have shown that boats and other sources of disturbance have a large influence on the present distribution of moulting ducks in the Wadden Sea. It is probable that the lack of moulting ducks in large areas is a result of disturbance in earlier years.

Conclusions

The populations of many bird species in the Wadden Sea have increased in the last decades and few have declined. The main factors for the increase of breeding birds are an improved protection during the breeding season, a substantial reduction in egg collection and reduced levels of pollutants.

Kentish plover and little tern populations have decreased which is due to a lack of sufficient undisturbed breeding habitats at beaches and in primary dune areas.

Important factors influencing population sizes within the Wadden Sea Area are, weather conditions, mussel fisheries, hunting and the availability of undisturbed breeding, feeding and moulting areas.

Mussel fishery interferes with the food availability of some bird species and is judged to be currently operating beyond sustainability levels in some parts of the Wadden Sea .

The reduced hunting pressure has a positive effect on the condition of birds.

Through disturbance by wind turbines, the number and size of roosting areas behind the dike have decreased.

6.8.5 Birds: Recommendations for management

Food availability

Management regarding food availability could include the closure of additional tidal flats to fisheries activities and the implementation of a quota system on the catch. The decision whether such measures are needed can only be taken after the assessment of fish and shellfish stocks.

With respect to the above mentioned problems, the following management measures would be useful:

- reduction of by-catch,
- reduction of mussel culture plots (with regard to the size),
- general avoidance of disturbance (see also potential feeding areas),
- reduction or cessation of cockle fishery,
- elaboration of management plans for herbivorous species on inland sites,
- reduction of eutrophication (see also 6.2).

Flight distances

Access to areas for humans should be made more predictable for birds, i.e. using only certain footpaths on salt marshes.

Creation of flight corridors for airplanes, especially helicopters and small aircraft.

To achieve this Target, or, at least, to work towards a decrease of flight distances, hunting must be terminated completely in the Wadden Sea cooperation area. In addition, political negotiations regarding a hunting ban in breeding areas and important stopover sites on the flyway of the birds should be supported.

Breeding success

Beaches are poorly protected habitats within the Wadden Sea Area. The aim of further cooperation on the breeding bird target must be to increase the proportion of beach habitats available for birds and to reserve the most preferred habitats, such as primary dunes, beach barriers, sand pits and shell banks, for birds. Especially, disturbances due to recreational activities must, were possible, be excluded from these places during the breeding season.

Roosting areas

Sufficiently large buffer zones around roosting sites should be created. Within these buffer zones, all human disturbing factors have to be minimized. These include not only direct human activities, but also infrastructure such as wind turbines and wind parks, which have an effect on flight routes and the usage of roosting places.

Moulting areas

A system of 'Seaduck-Reserves', which are closed to all shipping including fishing activities and other disturbance during the moulting period, must be designated. Spatial and temporal regulation of the closure for fishing boats can differ from that of watersports or other leisure activities. The quantification of a minimum size of these reserves is not possible but the enormous flight distances have to be kept in mind when designating these zones.

6.8.6 Birds: Recommendations for monitoring and research

Food availability

The direct food intake rate of birds cannot be measured within a monitoring program, however, some other parameters can give an indication of the food intake:

- development of the body mass of chicks (see also breeding success);
- departure weights of waders and geese in spring prior to their migration to the breeding grounds;
- investigations of regurgitated food remains (pellets) can show the composition of their diet.

These parameters should be monitored for selected species in special concomitant research projects in the framework of the TMAP.

The monitoring program must be supplemented by event-related research in cases of severe effects on food supply of bird populations, for example during cold winters with food shortage.

Flight distance

It is recommended to investigate the actual flight distances of birds in the Wadden Sea and to develop a standardized method for such measurements within an applied research project on the trilateral level.

Breeding success

Monitoring of breeding success should be carried out regularly to check the environmental conditions relevant for coastal birds. It can be used as an 'early warning system' for negative changes in birds' population sizes. It is also suited to determine the 'natural breeding success' of birds and to differentiate between naturally, and anthropogenically, caused changes. It is, therefore, recommended to continue the trilateral breeding bird pilot project.

Roosting areas

Research should be done to evaluate the situation of roosting sites and to find out the factors that determine the choice of roosting sites by birds in the Wadden Sea. The availability of suitable (natural) roosting sites as well as the regularly/naturally used flight routes between roosting and feeding sites in each country should be regularly evaluated.

Moulting areas

The counting of seaducks and boats by aerial surveys should be continued within the TMAP. Because the moulting area of, *i.e.*, shelducks are changing, the aerial surveys should be adapted to these changes.

6.9 Mammals

6.9.1 Common seal

With about 14,000 counted individuals in 1998, the common seal population is now much larger than before the 1988 epidemic (estimated size in 1987 10,000 individuals). An impaired immune system, due to pollution, has been postulated as a possible cause of the epidemic. The remarkable recovery of the population can be attributed to a higher reproduction rate and reduced initial juvenile mortality.

Although hunting has stopped, large areas are protected and the pollution level is much lower than in the 1970s, the populations are currently far from being unaffected by human activities, such as disturbance, change in physical habitat, interaction through fisheries, pollution and treatment and release of weakened seals. According to recent studies, disturbance in any form interferes with survival of the pups and site choice of the adults.

The present population size is still far below the estimated maximum size of some 37,000 individuals at the turn of the 19th to the 20th century. In the near future, the increasing population will demand more suitable habitats for hauling out. This will require a better tuning with other users of the area.

6.9.2 Grey seal

The grey seal population is also growing. There are now two reproductive colonies in the Wadden Sea with a respective size of 500 (NL maximum in 1999) and 30 to 40 (SH) animals. The present grey seal populations in the Wadden Sea cannot be regarded as viable. The stock in The Netherlands mainly grows because of immigration from Great Britain. Grey seals need high sands (not flooded during high tide) or beaches and salt marshes during whelping and nursing time in winter.

6.9.3 Harbour porpoise

Systematic aerial and shipping surveys have documented that about 340,000 harbour porpoises are distributed over the entire area of the North Sea. About 5,900 harbour porpoises were documented in the Schleswig-Holstein and the Danish part of the Wadden Sea. In comparison to other parts of the North Sea, there is an extraordinarily high density of mother calf-groups in this area and it may, thus, be concluded that it is an important rearing area for harbour porpoises.

Small cetaceans are especially sensitive to disturbance from high-speed boats (*e.g.* jet-skis) and by the impact of fishery (by-catch). The evidence of the effects of noise on small cetaceans is equivocal. They are often observed in areas where boat traffic is heavy. On the other hand, some species have been observed to respond to loud sounds at distances of several miles.

Incidental entanglement and mortality in fishing gear is a global problem affecting many species of small cetaceans. The effects of by-catch are probably the most important adverse impact to small cetaceans, especially to harbour porpoises.

6.9.4 Evaluation of the Targets with regard to marine mammals

Targets

Viable stocks and a natural reproduction capacity of the common seal, grey seal and harbour porpoise.

For the parameters 'viable stock' and 'natural reproduction capacity' no quantifications can be given. The reproduction capacity depends on a multitude of factors, such as water quality, disturbance and population size. The assessment of the viability of stocks will, therefore, have to based upon best experts' judgement.

Conclusions

The population size of the common seal is much higher than before the epidemic in 1988 although still far below the estimated maximum size of some 37,000 individuals. The population may be regarded as viable.

The grey seal population in the Wadden Sea is relatively small. The observed growth is also due to immigration from outside the area. There is insufficient knowledge to judge whether the population is viable.

Compared to other parts of the North Sea, the area west of Amrum, Sylt and Rømø has a high density of harbour porpoises. This area may be regarded as an important calving and nursing area for this species. Too little is known about the population dynamics of the harbour porpoise to be able to evaluate the Target for this species.

6.9.5 Marine mammals: Recommendations for management

In view of the rapidly growing common seal population, policies should anticipate problems connected with an increasing population such as availability of haul-out sites and conflicts with other users such as fisheries.

Of major importance for the protection management of the grey seal, is the fact that it needs undisturbed high sands (not flooded during high tide) or beaches and salt marshes during whelping and nursing time in winter.

Disturbance by boating and fisheries should be minimized in the area west of Sylt, Amrum and Rømø, which is an important rearing area for the harbour porpoise.

6.9.6 Marine mammals: Recommendations for research and monitoring

More knowledge is needed about the natural reproduction capacity and survival of grey seals in the Wadden Sea.

Regular monitoring of grey seal and harbour porpoise is necessary for an evaluation of the Targets regarding these species.

It is considered of high urgency to obtain data on bycatch of harbour porpoises as well as population data such as stock structure and abundance.

6.10 Executive Summary

6.10.1 Quality of Water, Sediment and Biota

Nutrients and eutrophication

Phosphate loads and concentrations have decreased in the past ten years. So far, this has 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.

Moreover, because nitrate loads and concentrations show no consistent decline, the nitrate/phosphate ratio has increased. So far, this has not caused an increase in the proliferation of toxic algae.

With regard to undesired eutrophication effects, it must, therefore, be concluded that the Target of a Wadden Sea which can be regarded as a eutrophication non-problem area, has not yet been reached.

- It is recommended to continue to implement current policies in the framework of the OSPAR Convention, The North Sea Conferences and the EU Nitrate and Municipal Wastewater Directives, especially with regard to nitrogen compounds.

Hazardous substances: Natural micropollutants

The loads of heavy metals from the Elbe, the major source of inputs to the Wadden Sea, have decreased significantly in the period 1985-1996.

Also, concentrations of metals in sediment have decreased and are approaching background levels. An exception is mercury for which levels are three to ten times higher than background levels.

The concentrations of all investigated heavy metals concentrations in sediment are lower than the provisional OSPAR ecotoxicological assessment criteria.

Concentrations of heavy metals in blue mussels generally show significant reductions in areas with previously high pollution levels. Zinc concentrations are within background range. Lead, copper, and cadmium concentrations are up to two times, mercury up to six times higher than the upper value of the OSPAR background range.

Mercury levels in bird eggs have significantly decreased in the Elbe estuary but averaged levels in 1996 in common tern were still three to five times higher than in other regions.

PAH levels are within the range of proposed background levels and well below the ecotoxicological assessment criteria.

- It is recommended to continue to implement current policies for the reduction of inputs of natural micropollutants, especially in view of the still elevated levels in biota.

Hazardous substances: Xenobiotics

Inputs of PCBs from the Elbe have decreased significantly between 1985 and 1996. Lindane inputs significantly decreased for most riverine sources.

Concentrations of PCBs in sediment show a steady decrease and organochlorine pesticides in bird eggs decreased in all investigated areas. PCBs in sediments in investigated Wadden Sea areas are within the OSPAR provisional ecotoxicological criterion range. The maximum of the firm ecotoxicological criterion for mussel, however, is exceeded with a factor of 3 in the Elbe estuary.

Hexachlorobenzene levels in eggs of the common tern in the Elbe estuary are up to 40-fold the prevalent Wadden Sea level.

The concentration of lindane in water in all estuaries is within the provisional OSPAR ecotoxicological assessment criterion range.

In several surveys, relatively high concentrations of xenobiotics have been detected. There is increasing evidence that certain pesticides hamper the grazing ability of zooplankton. Pesticides of the herbicide type interfere with the photosynthesis of phytoplankton. Pesticides may be a factor in the decline of littoral eelgrass.

TBT is highly toxic for several marine organism, amongst others whelks (*Nucella lapillus, Buccinium undatum*) and zooplankton species Levels in sediment have been shown to exceed the provisional OSPAR ecotoxicological assessment criterion up to a factor of 1000, even in the open Wadden Sea

- It is recommended to intensify relevant policies for the reduction of the application of pesticides and other xenobiotic compounds in the framework of OSPAR, the North Sea Conferences and the EU.
- The present data on TBT in sediment urge for a concerted investigation of all Wadden Sea areas.

6.10.2 Salt Marshes

Much has been achieved in the past ten years with regard to improving the natural situation in salt marshes by the reduction, or phasing out, of grazing and artificial drainage, but there are differences in policies among the Wadden Sea countries. In The Netherlands, the goal is to achieve a diverse vegetation structure through differenti-

ated grazing and the reduction of heavy grazing. In the German National Parks, the main aim is to gain a more natural distribution and development of flora and fauna in relation to local biotic and abiotic conditions by increasing the non-grazed area and reducing artificial drainage.

A precise comparison of the situation regarding the natural situation of salt marshes in the different parts of the Wadden Sea is presently not possible because of a lack of actual data and of common criteria.

The outbanking of summer polders has, so far, only been applied in the Dutch Wadden Sea. This practice not only increases the salt marsh area, but could also be favorable for creating new fresh-salt transitions and for maintaining the sediment balance of the Tidal Area.

The erosion of salt marshes does not yet seem to have increased as a result of sea level rise, bottom subsidence and higher wave energy, but a close monitoring of sedimentation patterns remains necessary.

- It is recommended that all partners in the trilateral cooperation prepare salt marsh policy plans.
- The possibilities for outbanking summer polders should be investigated more thoroughly and consistently

6.10.3 The Tidal Area

As a result of human interference, most notably fixed coastal constructions, but also fisheries, dredging sand extraction and gas extraction, the ability of the system to compensate for sea level rise may have decreased. Also, the settling conditions for fine-grained sediment may have become worse.

The implementation of the Tidal Area Targets should be based on an integrated assessment of all interfering human activities under different sea level rise scenarios. It is essential that the Tidal Area, the Salt Marshes and the Offshore Zone are considered as one system when dealing with hydrology and geomorphology.

The Target of an increased area and a more natural development of natural mussel beds, eelgrass meadows and *Sabellaria* reefs has not been reached. The decline in number and size of mature beds of the blue mussel and seagrass meadows has continued in this decade. The decrease of these structure-building communities may also influence hydrology and sedimentology in the Tidal Area.

- Our present understanding of the hydrological and geomorphological processes and their interactions, together with the role of mussel beds and seagrass meadows, is still insufficient to warrant reliable prognoses. There therefore is an urgent need for further research on the interactions between sediment composition, disturbances and dependent biotic developments.
- It is essential that the decision of the Esbjerg Conference (1991) to designate 'sufficiently large areas, spread evenly over the Wadden Sea, where all exploitation and disturbing activites are banned and which can serve as reference areas for scientific purposes' (ED, § 33.3), be implemented.
- There may be important differences in the interactions and the effects of human interference between different tidal basins in the Wadden Sea. Management should, therefore, in principle, be specified for individual basins.

6.10.4 Beaches and Dunes

The status of the dunes in the Wadden Sea Area has been, and still is, determined by conservative measures of coastal protection which preserve directly (planting of marram grass) or indirectly (building of sand dikes, groynes *etc.*) the zoning patterns. As a result, there is a relatively high percentage of intermediate stages and an underrepresentation of primary and oldest stages.

There are considerable differences in the percentage of primary dune area between the different barrier islands but, generally, it may be concluded that there is a considerable potential for implementation of the Targets.

It is expected that an increase in natural dynamics will also lead to a more natural vegetation succession.

The vegetation in dune valleys can be negatively influenced by increased groundwater extraction.

- An increase in natural dynamics in the dunes of most islands may be achieved by abandoning, reducing or modifying coastal protection maintenance works, depending upon local conditions, and as far as safety is not impaired.
- For a proper evaluation of the possibilities of implementing the Targets, it is necessary to carry out a detailed inventory into local factors relevant for dune management, in particular erosion-sedimentation patterns, exposure to storms and size of the island.

6.10.5 Estuaries

Only five estuaries have remained in the Wadden Sea area (Ems, Weser, Elbe, Godel, Varde Å). As a consequence, natural transitions of fresh and salt water hardly exist in the Wadden Sea Area.

The Varde Å and Godel are estuaries which have retained their natural character.

The Ems, Weser and Elbe and their tributaries have been modified considerably by diking 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 barrage in the Ems.

It must, therefore, be concluded that these estuaries are moving farther away from the Targets.

• The consequences of further deepening, barriers and harbor extension should be evaluated very carefully, taking into account the historic deterioration of the estuaries and the uniqueness of each estuary. There are still possibilities to restore estuarine habitats that have been lost by diking. The first step could be an inventory of the most suitable sites for outbankment.

6.10.6 The Offshore Zone

Both from physical and biological perspectives, the Offshore Zone and Tidal Area are closely connected.

From a geomorphological point of view, the Offshore Zone and Tidal Area have to be considered as one system.

The Offshore Zone is an important source of organic material for the Tidal Area.

It is also a food source and refuge for many invertebrate, fish and bird species and its role as breeding and nursing ground for the harbour porpoise has become more obvious in recent years.

• Because of the many interactions between Offshore Zone and Tidal Area, it is recommended that the management and protection of these two habitats be closely tuned. The evaluation of impacts in the Offshore Zone should also take into consideration effects in the Tidal Area and vice versa.

6.10.7 Birds

The populations of many bird species in the Wadden Sea have increased in the last decades and few have declined. The main factors for the increase of breeding birds are an improved protection during the breeding season, a substantial reduction in egg collection and reduced levels of pollutants.

Kentish plover and little tern populations have decreased due to a lack of sufficient undisturbed breeding habitats at beaches and in primary dune areas.

Important factors influencing population sizes within the Wadden Sea Area are, weather conditions, shellfish fisheries, hunting and the availability of undisturbed breeding, feeding and moulting areas.

Mussel fishery interferes with the food availability of some bird species and is judged to be currently operating beyond sustainability levels in some parts of the Wadden Sea .

The reduced hunting pressure has a positive effect on the condition of birds.

Through disturbance by wind turbines, the number and size of roosting areas behind the dike have decreased.

• Management regarding food availability could include the closure of additional tidal flats to shellfish fisheries activities and the implementation of a quota system on the catch.

• Access to areas for humans should be made more predictable for birds, *i.e.* using only certain footpaths on salt marshes.

• The aim of further cooperation on the breeding bird target must be to increase the proportion of beach habitats available for birds and to reserve the most preferred habitats, such as primary dunes, beach barriers, sand spits and shell banks, for birds.

• Sufficiently large buffer zones around roosting sites should be created.

• A system of 'Seaduck-Reserves', which are closed for all shipping including fishing activities and other disturbance during the moulting period, must be designated

6.10.8 Mammals

The population size of the common seal is much higher than before the epidemic in 1988 although still far below the estimated maximum size of some 37,000 individuals. The population may be regarded as viable.

The grey seal population in the Wadden Sea is relatively small. The observed growth is also due to immigration from outside the area. There is insufficient knowledge to judge whether the population is viable.

Compared to other parts of the North Sea, the area west of Amrum, Sylt and Rømø has a high density of harbour porpoises. This area may be

regarded as an important calving and nursing area for this species. Too little is known about the population dynamics of the harbour porpoise to be able to evaluate the target.

- Policies should anticipate problems connected with an increasing common seal population such as availability of haul-out sites and conflicts with other users such as fisheries.
- The grey seal needs undisturbed high sands (not flooded during high tide) or beaches and salt marshes during whelping and nursing time in winter.
- Disturbance by boating and fisheries should be minimized in the area west of Sylt, Amrum and Rømø, which is an important calving and nursing area for the harbour porpoise.