Chapter 17: Biodiversity of the Wadden Sea (Denmark, Germany, The Netherlands): recent changes and future projections

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INTRODUCTION

The Wadden Sea is a shallow estuarine area situated along the North Sea coasts of Denmark, Germany and The Netherlands. Average tidal ranges vary between 1.4 and 3.4 m. The Wadden Sea occupies about 8,000 km^2 and about half of this area consists of bare tidal flats. Salt marshes occur only above mean high water mark and cover about 300 km^2.

The Wadden Sea is considered to be one of the major nature areas of western Europe. Its tidal landscapes where natural processes such as erosion and accretion are visibly active, seem relatively unaffected by humans. The extensive tidal flats contain extremely large numbers of benthic invertebrates and are characterized by high biomasses. Also the subtidal areas are rich in individuals and biomass. On this invertebrate biomass fish and birds feed in very large numbers. Many North Sea fish and crustacean species use the Wadden Sea as a nursery. The bird population includes both breeding birds, such as gulls, terns,

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NATO ASI Series, Vol. I 20
Biodiversity, Temperate Ecosystems, and Global Change
Edited by T.J. B. Boyle and C.E. B. Boyle

and several species of shorebirds, and non-breeding migratory species. The latter species mainly breed in the Arctic and visit the Wadden Sea as a stopover site during migration or as a wintering site. Non-breeding migratory species include geese, ducks, many species of shorebirds, and several other species. It is estimated that altogether about 7 million shorebirds visit the Wadden Sea annually. Wolff (1983) gives an extensive description of the ecology of the Wadden Sea.

This paper attempts to describe changes in the biodiversity of the Wadden Sea during the period that man was able to interfere with its natural processes, i.e. the last thousand years, and to predict how biodiversity might develop from now under expected conditions of global change and local human impact. As will appear below, the Wadden Sea is very much under human influence, so next to global change of environmental conditions, developments in the local human society determine the fate of this coastal sea to a very large extent. Because of our ignorance about most of the development of our society over the next century, predictions about the development of the biodiversity of the Wadden Sea over a century make little sense. Even predictions for a period of 10-20 years are difficult.

PAST DEVELOPMENT OF BIODIVERSITY

The past development of biodiversity in the Wadden Sea has been summarized in two review papers by Wolff (1992a, in press). His conclusions are repeated below.

Natural situation

In a completely natural situation a Wadden Sea landscape would show the following sequence of belts of different landscape types when going from the North Sea to the higher inland areas:

- beaches and dunes on barrier islands
- salt marshes on barrier islands
- tidal flats and channels
- salt marshes

- brackish marshes
- freshwater marshes and swamps
- peat moors
- high-lying soils with forests and other dry vegetation types.

In the past, with rising sea level, these belts of different types of landscapes have moved inland and they would still do so when man had not interfered. At the same time sediment, mainly derived from barrier islands and the shallow sea floor in front of them, has been imported into this moving Wadden Sea. The outcome of these two processes has been dependent on the amount of sediment available, the tidal range and on the slope of the coast. Sometimes areas of open water and tidal flats filled in, sometimes they enlarged.

Embankments and reclamation

Until about 1000 years ago man hardly interfered with the geomorphological development of the Wadden Sea. Although the coastal area was fairly densely populated, people lived on naturally elevated areas and on artificial mounds and did not seriously interfere with the tidal movements. At that time, however, the invention of dike-building introduced a major change (Wolff, 1992b). In the beginning only rather small areas in the highest parts of the coastal region were were surrounded by low dikes. Soon however these areas were connected by other dikes and at the end of the 12th century the larger part of the vegetated landscape was separated from the tidal Wadden Sea by a contiguous system of dikes. Outside these dikes large salt marsh areas still occurred. Gradually, however, these and newly accreting salt marshes were reclaimed and turned into farmland (Dijkema, 1987). Thus the connection between the Wadden Sea and the adjacent belt of brackish and fresh wetlands was broken.

This separation of the Wadden Sea from its coastal marshes and peat moors may well have been the most important intervention in its history. However, since it was long ago, we are inclined to neglect this major change of the Wadden Sea

ecosystem and we tend to consider the present-day Wadden Sea as the normal situation.

The result of all embankments and reclamations is a very marked and firm separation between the tidal Wadden Sea on the one hand and the non-tidal land and freshwater areas on the other hand. In the remaining, estuarine part of the Wadden Sea these geomorphological changes probably did not cause major changes of biodiversity, but at the landward side of the dikes a landscape of fresh and brackish wetlands was changed into agricultural landscapes at the cost of great losses of biodiversity. The dikes and dams constructed in between Wadden Sea and mainland also constitute a major barrier for transport of materials and for migratory aquatic organisms.

The engineering works of the past have had an influence on the tides and the tidal currents. Usually the changes were only slight, but in the case of the closure of the Zuiderzee in The Netherlands the tidal amplitude in the remaining part of the Wadden Sea increased by about 50%. This change in the tidal dynamics may have been an additional factor in the disappearance of seagrasses from the Dutch Wadden Sea (Van den Hoek *et al.*, 1979). They also caused erosion of the few salt marshes which still occurred at that time.

Due to the construction of dikes and dams the gradual transition between the sea on the one hand and the fresh water on the other hand became much more abrupt. Gradual transitions of salinity with a variety of brackish water types disappeared and with them the ecological conditions of these different types of waters vanished. This is especially true for the types of brackish water with only slow and/or slight temporal changes of salinity, such as the former Zuiderzee, a brackish lagoon of about 3700 km^2 in The Netherlands. Thus several characteristic brackish-water species such as the Zuiderzee crab *Rhithropanopeus harrisii* tridentatus and the nudibranch Corambe batava have virtually disappeared from the Wadden Sea area (Dankers *et al.*, 1981).

Introduction of species

Table 1 presents an incomplete list of species known to have been introduced from abroad into the Wadden Sea area by human intervention. Most species were inadvertently introduced, some like the cord grass Spartina townsendii and the Japanese oyster *Crassostrea gigas* deliberately for, respectively, stimulation of accretion and oyster farming. In most cases we have no indication that the original Wadden Sea ecosystem was upset because of the new species. Only in the case of *Spartina* rather far-reaching changes in the vegetation of salt marshes were observed (Beeftink, 1977).

Most species introduced from other continents arrived here in unknown ways. In some cases, e.g. those of the Chinese mitten crab *Eriocheir sinensis* and the New-Zealand barnacle *Elminius modestus*, it is reasonably well established that transport in ballast water or on the hull of ships has been the cause and the same way of transport may be suspected for many other species (Carlton & Geller, 1993). Another way of introduction is transport on imported shellfish. This is, of course, true for the shellfish species themselves, such as the Japanese oyster *Crassostrea gigas*, but also for the species attached to the shells, such as the Japanese alga *Sargassum muticum*.

Other new species were able to colonize the Wadden Sea because their habitat was introduced there. The best example is the construction of artificial rocky shores in the form of breakwaters, moles, and stone-covered dike slopes. Before hardly any hard substrates occurred in the area. Many rocky-shore species such as the kelp *Laminaria saccharina* have colonized these shores (Den Hartog, 1959).

Summarizing it may be concluded that the Wadden Sea nowadays lodges quite a number of species of algae and invertebrates which did not occur there before. Most of these species have in common that they are relatively small and short-living and that they have short reproduction cycles. They did not change the ecosystems very much, and they certainly increased local biodiversity. On the

Table 1. Some species introduced into the Wadden Sea area due to human intervention. After Wolff (1973), Den Hartog & Van der Velde (1987), Essink (1985) and Essink & Kleef (1988).

Algae	
Asterionella japonica	Pacific
Codium fragile	Pacific
Sargassum muticum	Pacific
Vascular plants	
Spartina townsendii (*S. anglica*)	America - England
Coelenterata	
Cordylophora caspia	Caspian Sea
Garveia franciscana	America
Mollusca	
Corambe batava	America
Crepidula fornicata	America
Crassostrea gigas (*C. angulata*)	Pacific
Teredo navalis	?
Ensis directus	America
Petricola phola	America
Mya arenaria	America
Polychaeta	
Marenzelleria viridis	America
Crustacea	
Balanus improvisus?	?
Elminius modestus	Pacific
Eriocheir sinensis	Pacific
Rithropanopeus harrisii	America
Tunicata	
Molgula manhattensis	America
Styela clava	America

other hand, because of their usually already widespread distribution, their addition hardly enhances biodiversity on the larger scale.

Extinction of species due to human activities

On the other hand, human activities have had such a strong impact on the Wadden Sea ecosystem, that several species have become extinct. In many cases the cause has been identified or at least can be suspected.

The fossil and archaeological records show that Grey whales (*Eschrichtius gibbosus*) once occurred in the North Sea area. The Grey whale is now extinct in the Atlantic Ocean and its adjacent seas (Mitchell 1974, Mitchell and Mead 1977). De Smet (1976) presents evidence for mediaeval whaling in the North Sea and the English Channel and believes that both the Grey whale and Atlantic right whale (*Eubalaena glacialis*) may have been involved. He assumes that these slow species had been exterminated in the North Sea and English Channel area already in the Middle Ages. De Smet therefore suggests that the Grey whale once used the Wadden Sea as a breeding ground.

Subfossil remains of Grey seals (*Halichoerus grypus*) are rather common in prehistoric settlements and it is likely that our ancestors hunted this species. Because its pups stay on dry land for several weeks, these will have been an easy prey, and hence it may be assumed that in the Wadden Sea area it became an early victim of overexploitation (Reijnders, 1978; Reijnders *et al.*, 1992). This provides a likely explanation for the absence of Grey seals from the Wadden Sea from the late Middle Ages until quite recently.

How quickly overexploitation of marine mammals can reduce their populations, shows in the example of the Harbour seal (*Phoca vitulina*) in the Netherlands in the fifties. In that period virtually all juveniles were killed because of their furs, resulting in a population decrease of about 60-70% in about 10 years (Van Haaften, 1974; Reijnders, 1976).

Slowly reproducing large birds are also very vulnerable to exploitation or deliberate killing. This may explain why several species which elsewhere in the Northern Hemisphere have a large breeding distribution do not occur in the

Wadden Sea area, although the area seems to be suitable. Examples are Little Egret (*Egretta garzetta*), White-tailed eagle (*Haliaetus albicilla*), Osprey (*Pandion haliaetus*), Black Kite (*Milvus migrans*), and Caspian tern (*Hydroprogne caspia*). According to Pliny (Voous, 1960) Dalmatian Pelicans (*Pelecanus crispus*) also have occurred in the Wadden Sea area.

Also smaller birds have become victim of exploitation, mainly because their eggs were collected by the coastal population. Although a few colonies of gulls and terns (Eijerland-Texel, Rottumeroog, Sylt?) were exploited on a sustainable basis (Swennen, 1982), many other colonies will have disappeared as have populations of species breeding as single pairs. This exploitation of eggs explains why at the beginning of this century Eider duck (*Somateria mollissima*), Lesser black-backed gull (*Larus fuscus*), Herring gull (*L. argentatus*), Common gull (*L. canus*), and Avocet (*Recurvirostra avosetta*) were quite rare along the shores of the Wadden Sea (Leege, 1905).

Fish species may also have become rare because of exploitation, especially the larger, slowly reproducing species. This probably applies to Thornback ray (*Raja clavata*), Sting ray (*Dasyatis pastinacea*), and Dogfish (*Scyliorhinus caniculus*). In this case it is probably not, or at least not in the first place, the result of Wadden Sea fisheries, but that of intensive bottom-trawl fisheries in the entire North Sea, in which these species mainly occur as by-catch. The effects of river fisheries on several anadromous species probably have been similar. It may be suspected that up to the Second World War these fisheries had a strong impact on populations of species such as Sturgeon (*Accipenser sturio*), Salmon (*Salmo salar*), Allis shad (*Alosa alosa*), and Houting (*Coregonus oxyrhynchus*). However, nowadays the river fisheries have largely disappeared and their possible effects are overruled by the effects of river regulation and population.

A clear example of overexploitation in the Wadden Sea itself is the disappearance of the Wadden Sea oyster (*Ostrea edulis*) beds. Once flourishing oyster fisheries existed in the Dutch Wadden Sea and in Nordfriesland in Germany. These have completely disappeared because of overfishing. Thus the classic ecosystem study of Moebius (1877) can never be repeated because its subject has

been extinguished. Recently intertidal mussel beds have disappeared from the Dutch Wadden Sea due to overexploitation. Reise (1982) and Reise *et al.* (1989) have documented this change in the composition of the benthic fauna in the Nordfriesland Wadden Sea in Germany. Long-living species, such as several species of molluscs, gave way to opportunistic species, mainly polychaetes. This pattern is not restricted to Nordfriesland, however. It is also recognizable in Dutch coastal waters (Horst, 1883-84; Wolff, 1973; Dekker, 1989). For the deeper parts of the Wadden Sea, Reise attributes this change mainly to fisheries and especially those forms with heavy bottom gear. It is not only a change in species, but also a change of ecosystems. In the old days oyster beds, Sabellaria reefs, sublittoral seagrass beds and "meadows" of hydroids were easily recognizable systems with a characteristic flora and fauna. These features now hardly or longer exist in the Wadden Sea.

Extinction of species due to habitat loss

Some species have disappeared because their habitats disappeared. One example is the Zuiderzee race of herring (*Clupea harengus*), which lost its spawning grounds because of the closure of the Zuiderzee. Within a few years it became virtually extinct (Havinga, 1954). After the herring disappeared the bottlenose dolphin (*Tursiops truncatus*) also failed to appear in spring (Verwey & Wolff, 1981). The disappearance of invertebrate brackish-water species in the same area due to the same cause has already been mentioned above. At the time of the closure of the Zuiderzee, the seagrass beds in the remaining part of the Dutch Wadden Sea disappeared and never returned. Their disappearance probably was due to the so-called "wasting disease", a wide-spread natural phenomenon at that time; the failure to return is probably due to the closure of the Zuiderzee which changed hydrographical conditions in the remaining area. With the disappearance of their seagrass habitat several plant and animal species also disappeared from the entire Wadden Sea: among others the sea stickleback (*Spinachia spinachia*), the deep-snouted pipefish (*Syngnathus typhle*), and the gastropods *Rissoa membranacea* and *Lacuna vincta*.

Effects of pollution

Pollution has obtained much attention, but so far its effects have been less far-reaching than those of some other human interventions in the Wadden Sea. No species is known with certainty to have disappeared from the Wadden Sea because of pollution.

Chlorinated hydrocarbons, however, have had very strong effects on the populations of many Wadden Sea birds, especially in the Netherlands but also in Germany (Koeman, 1971; Becker & Erdelen, 1987). Species such as Eider duck, Spoonbill (*Platalea leucorodia*), and Sandwich tern (*Sterna sandvicensis*) decreased very sharply in the sixties, and only started to increase again when the cause of pollution had been removed. However, after 25 years the tern populations have not yet returned to their original levels.

Since the sixties the Dutch population of Harbour seals showed a continuous decline due to the effects of polychlorinated biphenyls (PCB's) (Reijnder, 1986) until the decrease was balanced in the eighties by immigration of seals from Germany. At it lowest level, less than 10% of the original Dutch seal population was left. Whether the Habour porpoise (*Phocoena phocoena*), another marine mammal, has become extinct in the Wadden Sea because of PCB pollution, as has been suggested several times, is doubtful (Reijnders, 1992).

Introduction of species for cultivation

Cultivation in the Wadden Sea at present is restricted to blue mussels (*Mytilus edulis*) and Japanese oysters. Especially with mussel cultivation, it is clear that it changes the environment and thus promotes possibilities for a number of species. Apart from the mussels, Eel (*Anguilla anguilla*) and Starfish (*Asterias rubens*) can be considered as examples. It has also been suggested that Eider ducks have increased because of mussel cultivation.

Effects of nature conservation and environmental protection

Wadden Sea conservation dates back to 1909 when the island of Jordsand, at that time part of Germany, was protected. Under Danish rule the protection was

restored in 1922. Protection of the islands of Griend in the Netherlands and of Mellum in Germany followed in 1917 and 1924, respectively. Thus originally conservation in the Wadden Sea aimed at the protection of the most important breeding colonies of coastal birds, but after the Second World War the salt marshes with lower numbers of birds also gradually became protected. Protection of the Wadden Sea itself started in Germany with the reserve "Wattenmeer ostlich Sylt" in 1973. However, this and other large reserves established in the German Wadden Sea in later years lacked a management organisation. The Netherlands protected most of the the Dutch Wadden Sea by application of the Nature Conservation Act in 1981 and at the same time a management organisation was set up. Three national parks in Germany followed in respectively 1985, 1986 and 1990. Denmark protected its Wadden Sea in 1979 as a game reserve and in 1982 as a nature reserve.

Protection of breeding colonies has proved very successful. Breeding populations of almost all species of coastal birds have shown an exponential increase since the beginning of this century (Swennen, 1982).

The recent protection of the Wadden Sea itself probably has prevented some negative developments, but it has not yet produced clear positive ecological changes. Perhaps the return of the Grey seal as a breeding species may be viewed as such (Reijnders *et al.*, 1992). Three major reasons for the lack of positive changes are the short period since Wadden Sea conservation started, the exceptions allowed to several conservation measures, and the fact that conservation problems have shifted from local impacts such as overexploitation, which can be counteracted by the creation of reserves, to widespread negative impacts on the environment such as pollution by chlorinated hydrocarbons. Such impacts are not restricted by reserves but instead need a strict environmental policy.

Indeed, environmental measures have already resulted in positive ecological changes. After the widespread mortality of seabirds in the western part of the Wadden Sea due to discharge of pesticides at the Rhine estuary, measures taken to decrease these discharges have resulted in a strong increase of the populations concerned (Smit & Wolff, 1981; Swennen, 1982).

Measures to reduce the discharge of organically enriched waste-water have resulted in lasting recolonization by benthic invertebrates of tidal flat areas depopulated earlier because of frequent absence of oxygen (Essink, 1984).

Conclusions on past changes of biodiversity

The following general conclusions may be drawn on the past changes of biodiversity in the Wadden Sea:

- in a seemingly natural area humans appear to have had a very strong impact on biodiversity; already in the Middle Ages half of the ecosystem had been destroyed;
- many large, long-living and slowly reproducing species (K-selected species) have disappeared from the Wadden Sea, whereas many small, short-living and rapidly reproducing species (r-selected species) have colonized the area or increased in numbers; and
- nature conservation and environmental protection so far have only had limited results with regard to biodiversity. Positive responses have mainly been shown by more opportunistic species (r-species).

FUTURE PROJECTIONS OF BIODIVERSITY

Possible scenarios for development of the Wadden Sea

The abiotic environment of the Wadden Sea is expected to change as a consequence of climate change. The ecological consequences of the expected changes for the Wadden Sea and other coastal seas and estuaries have been investigated at a workshop in Texel, the Netherlands, in 1988 (Beukema *et al.*, 1990), assuming that the worldwide scenario developed and used by the Intergovernmental Panel on Climate Change can also be applied to the local situation of the Wadden Sea. However, until now, Global Circulation Models are not sufficiently detailed to make meaningful predictions for small areas. Bearing this in mind we have, nevertheless, used the current worldwide IPCC scenario to predict the main changes in the Wadden Sea.

- Present tectonic subsidence of the Wadden Sea area and worldwide "normal" rise in sea level are expected to be reinforced by sea level rise due to climate change. Locally and temporally this trend is reinforced again by subsidence of the tidal flats and slat marshes due to extraction of natural gas. For the next 10-20 years the rise of sea level is not expected to move outside the range of sea level which has occurred up to now; over the next 100 years sea level rise may be much larger than has occurred over the past centuries.
- Worldwide change of climate may result in local changes of temperature, precipitation, wind force and wind direction, etc. For the next 10-20 years the changes in the Wadden Sea area are supposed to be small; over the next 100 years important, but until now the changes which may occur are unknown.

The Wadden Sea is also subject to trends in human impacts. In this part of western Europe, *i.e.* a highly developed and densely populated part of the world, the social trends listed below are believed to be important for the Wadden Sea. Lacking better alternatives they have been extrapolated to the next 10-20 years in order to provide scenarios for human impacts. For periods longer than this meaningful scenarios can hardly be made.

- Population density continues to increase slowly. In combination with increases in leisure time and affluence this results in an increased demand for recreation opportunities, among which are active forms of recreation in natural areas.
- Food production becomes more and more concentrated in highly developed cultivation systems. In coastal waters free fisheries are replaced by maricultures requiring less space, but more energy, and producing more wastes. Land reclamation for expansion of agriculture becomes very unlikely (Wolff 1992b).
- International trade continues at least at the same level resulting in the introduction of ever more species from all parts of the world.

- Although some sources of pollution may be increasing, environmental protection becomes more strict. Already the water quality of the rivers debouching into the Wadden Sea shows enormous improvement and it is expected that this trend will continue. The same applies to air pollution. However, whereas "simple" forms of pollution are likely to disappear, or at least greatly decrease, "difficult" forms, such as PCB's and dioxins, are likely to continue to occur, or even increase, because large quantities are still making their way into the marine environment.
- Nature protection changes from a defensive to an offensive strategy.

Scenarios for the management of the future Wadden Sea

At the seventh International Wadden Sea Symposium held on the island of Ameland, the Netherlands, in 1990 (Dankers *et al.*, 1992) four scenarios for the future management of the Wadden Sea were presented:

- multifunctional use of the Wadden Sea, at the same time aiming for a high nature conservation value (Essink 1992);
- a Wadden Sea "free-for-all", without any limits on human exploitation of the area (Muus 1992);
- the Wadden Sea as a pristine nature reserve (Reise 1992); and
- the Wadden Sea in maximum sustainable use (De Vals 1992).

Reise (1992) concluded that a pristine Wadden Sea is impossible to achieve; the maximum possible is probably a number of smaller "zero-use" areas. Similarly, a Wadden Sea free-for-all (Muus 1992) seems very unlikely at present, given the common attitude to protection of natural areas in western Europe. The scenario aiming for maximum sustainable use (De Vals 1992) seems a more likely option at the moment, although it is not in line with the present trends in society as described above. This is the case, however, for the scenario aiming at multifunctional use with a high conservation value (Essink 1992). This scenario extrapolates present ideas and policies, and hence seems the most likely option.

Remarkably enough, global change was hardly incorporated into these four scenarios.

Future projections of biodiversity in the Wadden Sea

Combining elements from these management scenarios with the scenarios for trends in society and environment identified above, we believe that the following developments in the Wadden Sea are possible in the next 10-20 years. In addition, we suggest some possible changes for the next 100 years.

- A very limited impact of climate change is expected for the next 10-20 years. Perhaps a few species of plants or invertebrates from lower latitudes may succeed in establishing themselves temporarily or permanently. However, in view of the species composition of the ecosystems occurring in estuaries further south along the European coasts, we expect only minor ecological changes (see also De Vooys 1990). Over a period of about 100 years more introductions are expected, including new breeding birds and fish species (Costa 1990). Some wintering bird species may disappear, however, because of a shift in their wintering areas to the north, of because of climate induced changes in their northern breeding ranges.
- A very limited impact of increased sea level rise is expected for the next 10-20 years. The Wadden Sea system will largely be able to compensate the expected rise by accretion. Only in some of the saltmarsh areas may present trends in erosion aggravate, resulting in decrease of total marsh area. However, species loss is unlikely in this period. Over 100 years the loss of salt marshes, especially at the barrier islands, may become more serious (Dijkema *et al.* 1990) and some salt marsh plants or invertebrates, already rare at this moment, may disappear from the area altogether. No species losses from sea level rise are expected for tidal flat habitats or shallow water environments.
- Environmental protection in the next 10-20 years is expected to result in a situation in which many noxious substances have decreased very strongly. No further problems are expected from raw sewage, nutrients, heavy metals,

and many pesticides. However, persistent organohalogens are expected to continue to occur in quantities which may have negative effects on biodiversity, especially with regard to the occurrence of marine mammals. The situation over the next 100 years cannot be predicted.

- International trade and transport will continue to introduce new species into the Wadden Sea at a rate of at least 2-3 species per 10 years. In most cases these newcomers will be invertebrates and cryptogamic plants; based on experience gained up to now it is expected that their impact on the existing ecosystem will be slight. Extinctions of indigenous species due to introductions of new ones are expected only as an exception, so there is a net increase of local biodiversity.
- Present trends in society during the next 10-20 years will probably result in a Wadden Sea area in which a considerable part is strictly protected and well guarded, whereas the remainder of the area is open for use by quite a number of human activities. It is expected that areas embanked in earlier centuries will be turned into tidal landscapes again. In the protected areas the present trends of species returning after many years of absence will continue. It is expected that especially the smaller, rapidly reproducing species will profit from this situation. It seems unlikely that large and slowly reproducing species, such as the Dalmation pelican, White-tailed eagle, and Osprey, will return in this situation and within this period. An additional reason is that these species were probably also dependent on the former marshy fringes of the Wadden Sea. Absent species of North Sea fish will not return because the reason for their absence continues to occur outside the Wadden Sea. Anadromous species are likely to return, however, due to the present clean-up and restoration activities in the rivers. It does not make sense to predict the development of society and hence its biodiversity effects over a period of 100 years.

Altogether, we expect for the next 10-20 years a trend of slowly increasing biodiversity in the Wadden Sea. What will happen on a longer time scale is a

matter of conjecture. An interesting additional conclusion is that the expected effects of local human activities have an impact which is at least of the same order of magnitude as the effects of climate change.

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