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The Outstanding Universal Values of the Wadden Sea: an ecological perspective

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Summary

This report describes the Outstanding Unique Values of the Wadden Sea from an ecological perspective, that is, according to criteria IX and X for the nomination of World Heritage Sites, as defined by the IUCN World Commission on Protected Areas.

The Wadden Sea is an outstanding example of the Holocene development of a sandy coast under conditions of rising sea level and is unique in that it is the largest extensive tidal flat and barrier island depositional system in the World. Its geological and geomorphological features are closely entwined with biophysical processes (biogeomorphology). The biogeomorphological interactions are notably strong and unique on all scales.

The rich and diverse habitats are of outstanding international importance as an essential habitat for of migratory water birds using the East Atlantic Flyway and other migration routes between South Africa, Northeast Canada, and northern Siberia. It is one of the few shallow seas in the Northern Hemisphere with a relatively high production of fish and serves as a nursery area and an essential staging area for species migrating between freshwater and saltwater for spawning and feeding.

The proposed property encompasses all the biophysical and ecosystem processes that characterise a natural and sustainable Wadden Sea. The standards of protection, management and monitoring ensure that the natural Wadden ecosystem, with all its component parts, will continue to evolve naturally and to sustain human uses for the foreseeable future. Man's use of the natural resources in a sustainable way including traditional resource use is a key to guarantee its integrity for generations to come.

1 Introduction

Since the Esbjerg Wadden Sea Conference in 1991, the nomination of the Wadden Sea as World Heritage Site is being prepared. In recent years progress is high; since 2005 The Netherlands and Germany are working hard on the preparation of a nomination dossier.

The ministry of Agriculture, Nature and Food Quality is co-ordinating the nomination on behalf of the Dutch government. They have requested IMARES, location Texel, to report the Outstanding Universal Values of the Wadden Sea with regard to criteria IX and X. These criteria describe the most important and unique on-going ecological processes and the biodiversity in the nominated site. In addition, the natural integrity of the site should be assessed, the protection and management status should be described and a comparative analysis of other similar sites around the world should be made. This knowledge subsequently feeds into Chapter 3 of the nomination dossier and the complete text of this report will be incorporated as an appendix to the dossier.

This report consists of two chapters that refer to the criteria IX and X as defined by the IUCN World Commission on Protected Areas, and a list of references.

2 Criterion ix

"be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals"

Physical processes shaping shallow coastal zones can be found anywhere in the world. The Wadden Sea, however, is of a special kind. It is the only non-tropical extensive tidal flat and barrier-island depositional system in the World (see criterion viii) (Wolff, 1983). Very characteristic are the non-fixed, and therefore 'walking islands' or considerable parts of islands. Of a special kind are the biogenic structures such as reefs of oysters, mussels or tube-building worms that affect the morphology as 'ecosystem engineers'.
Its sheer size gives rise to a multitude of biophysical and ecological processes that cannot be found within one system anywhere else. The Wadden Sea is characterized by a *complete system of gullies and flats*, i.e. an outer delta, a tidal inlet and a basin with ebb- and flood gullies that end in very small '*prielen'*. The completeness of this system, which is found in a fractal manner, is extraordinary; see Figs. 1, 2 and 3. The tidal-channel systems can be regarded as 'statistical self-similar fractal'networks and the similarity of the channel systems points to a self-organising nature (Cleveringa & Oost, 1999). On smaller scales, fractal patterns are also found in the muddy deposits. Moreover, the spatial distribution of intertidal benthic communities shows fractal patterns as well. Intertidal mussel beds in the Wadden Sea, for example, show a spatial self-organisation (Van de Koppel et al., 2005).
Interestingly, the origin of fractal patterns in ecosystems can have seven different explanations (Halley et al., 2004). For benthic communities two possible explanations are likely: The first is that a fractal distribution of abiotic factors presents a template upon which organisms and communities operate. The second is that a fractal spatial pattern is a result of community self-organisation which is transformed in spatial structures under environmental influences (Azovsky et al. 2000). A final answer has not been given yet. It is known that complex spatial patterns affect ecosystem processes such as resource utilization, movement of organisms and redistribution of nutrients, and that they support more complex ecological communities (Turner, 1989; Levin, 1992). Research focusing on the linkages between scales, ecological processes and complexity is a central problem in biology. The Wadden Sea is a prime example.

An ecosystem can only function in an optimal state when all physical, chemical, geomorphological and biological processes can operate in an undisturbed and coherent manner and in a functional relationship. When a system is large enough and many parts are relatively undisturbed there is a big chance that this will be the case for the system as a whole. The Wadden Sea fulfills this criterion.

Fig. 1. Pattern of gullies in the Eijerlandse inlet between Texel and Vlieland (scale 30x30 km)

Fig. 2. Pattern of 'prielen' on a tidal flat (scale 200 x 200 m) (Photo courtesy Martin de Jong, IMARES).

Fig. 3. Pattern of very small ' prielen' on a tidal flat (scale 1x1 m) (Copyright Waddenvereniging).

The Wadden Sea is a relatively young system that has developed because of sea-level rise in the past 6000 years (Beets & Van der Spek, 2000). It has a *variety of flat types*, ranging from coarse sand in the inlet, up to silt and mud along the inner margins and at the *tidal divide* behind the barrier islands. Some flats emerge only shortly, others only inundate during storm floods. In an interplay of physical, ecological and biological processes specific structures or even landscape size forms develop. On the shore, where vegetation can grow, *coastal dunes* form in the more exposed, sandy parts and *saltmarshes* in the sheltered, muddy parts. In the tidal flat itself, extremely high densities of specific animal species influence the system in such a way that they form biogenic structures such as mussel beds, oyster and *Sabellaria* reefs. To our knowledge, such biogenic reefs in non-tropical waters have not been listed before in World Heritage Nominations.

The whole range of these geomorphological and biological structures and communities occur in a functional relationship, making the Wadden Sea a 'complete' ecosystem. This means that functional relationships are found on all spatial and temporal scales in coherence with each other. Its completeness and size make the Wadden Sea an outstanding and unique non-tropical ecosystem. Furthermore, due to the estuarine influence of the Rhine (although through sluices) and Eems, Weser, Elbe, Eider and Varde Aa one finds density-driven currents, a turbidity maximum and a biological richness including migratory fish and brackish species.

Physical drivers, such as tides, wind, currents, waves, and biological processes, such as competition for resources, occurring in a large area have resulted in the richness of geomorphological and biogenic structures found. Due to the undisturbed presence of these processes, structures are not only conserved, but there are also rejuvenation cycles, creating new structures and breaking down old structures. Examples are the dunes and saltmarshes that can be found in all stages of succession, and structured mussel banks, which are formed by a combination of growth and food depletion from the overlying water (Van de Koppel et al., 2005).

As a shallow sea, the benthic-pelagic coupling is notably strong, and the primary and secondary production are high. This production forms a foundation to the intricate food web that ultimately results in an important nursery area for fish, a foraging and resting habitat for seals, and a foraging habitat for waders, which will be discussed later in more detail. These functions of the Wadden Sea, and specifically its importance as a nursery area, were the main arguments in the 1970s not to embank this system, and it still serves as a prime example of the change in attitude in large scale conservation of ecosystems on landscape scale. In the US at that time the emphasis was laid on the function of saltmarshes in production and export of organic matter and nutrients to the coastal ecosystem. In the case of the Wadden Sea the emphasis was more on its specific value in combination with the services to surrounding ecosystems.
The Wadden Sea has an intrinsic relationship with the North Sea. The North Sea is one of the few shallow and relatively sheltered seas in the Northern Hemisphere with a relatively high production of fish. The combination of a large, shallow and highly productive sea combined with a system like the Wadden Sea is unique on a world scale (Wolff, 1983).

a) Primary and secondary production

One of the outstanding features of the Wadden Sea is that the in situ primary production is to a large extent the result of benthic production. In coastal zones in general, the phytoplankton production dominates, but the Wadden Sea is unique in its enormous surface area of emerging tidal flats that host high densities of microphytobenthos. The contribution of microphytobenthos to the primary production is about as high as the primary production by planktonic algae (Cadée & Hegeman, 1974a and b; Asmus et al., 1998). The gross primary production by microphytobenthos, which reaches values of over 1000 mgC m^{-2} d^{-1}, is the highest in the world for locations north of 42° latitude (MacIntyre et al., 1996, Table 4). Next to the in situ production there is a large net import of algae produced in the coastal regions of the North Sea.
Because of the abundant supply of algae, the secondary production is large, as well. The sandy and muddy bottoms host a variety of macrozoobenthic herbivores, which can reach locally high

densities. Not only phytoplankton, but also benthic diatoms are an important food source for filterfeeding bivalves. Suspended microphytobenthos may represent up to 50 % of the microalgae in the water column and thus of the food of filterfeeders (De Jonge, 1985, Fig. 7).

b) Biogenic structures and biogeomorphology

Due to the shallowness of the area and the fuzzy boundaries between land and sea, there is a strong interaction between biota and geomorphological processes, i.e. biogeomorphology (Baptist, 2005; Stallins, 2006).

The geomorphological influence on biota is in its most direct form the influence on habitats of flora and fauna. The Wadden Sea morphology and geomorphological processes therein define gradients between high and low, wet and dry and sedimentation and erosion. These gradients and the processes that cause them are determinative for gradients in grain size of the sediment, nutrient levels, organic matter levels and moisture. Plants and animals are tuned to specific conditions and will therefore be abundant in specific locations, i.e. there habitats. In the coarse grained and dynamic sediments a large abundance of specific polychaete worms (*Scolelepis squamata*) occurs with densities of up to 300 grams/m^2. In the more sheltered parts the flats are abundant with worms and cockles. Mussel beds are recovering after closure of fisheries, and in dense beds of shellfish, biomass may reach values of more than 50 kg per m^2.

Conversely, the biological influence on geomorphological processes is the influence of biota to create, maintain or transform their own geomorphological surroundings. This is demonstrated by the influence of vegetation on the hydraulic resistance, erodibility and sedimentation, or by the influence of fauna on sediment characteristics through bioturbation and biostabilization.

The Wadden Sea forms an outstanding example of biogeomorphological interactions (see Box). Important in this respect is that the Wadden Sea has many examples in which the timescale for geomorphological changes coincides with the timescale for biological changes. This results in mutually interacting processes. Unlike other areas in the world, landscape processes are not dominated by geological timescales nor do biological processes dominate landscape features. This means that the constantly changing landscape requires adaptation of organisms and at the same time that organisms affect their environment as ‘ecosystem engineers’. Excellent and broad scale examples of these biogeomorphological interactions can be found in the dunes, the tidal flats and the saltmarshes. Of particular interest are for example the intertidal mussel beds. These form a biogenic structure that has considerable influence on the morphology of the tidal flats; they stabilize the sediment, preventing it from erosion and actively accrete silt. The numerous macrobenthic species can have an opposite effect. Their constant reworking of the sediment (bioturbation) makes the bed more susceptible to erosion. Saltmarshes form another example in which the capturing of silt increases the bed level, which leads to changes in vegetation composition and subsequent changes in sedimentation rates.

The important ecosystem types in the Wadden Sea (ecotopes or habitats) are those which are formed and maintained by an interplay of physical and biological processes. This interplay is essentially an interaction of on-going geological processes in the development of landforms and on-going ecological and biological processes. This feature cannot be described under criterion viii or criterion ix separately.

Biogeomorphology in the Wadden Sea

Physical processes in the Wadden Sea and its estuaries, such as flow, tides and waves, are responsible for the mixing of the water column, the transport of sediment and the transport of nutrients and organisms. Sandy coasts with small tidal amplitude develop into a system of barrier-islands with intertidal flats between the islands and the mainland. The tidal currents together with wind and wave action are responsible for the maintenance of gullies and tidal flats. The Wadden Sea system is characterized by complete gully system. That means a tidal inlet, ebb and flood systems and main channels, which branch into small gullies and creeks in sandy or silty areas or salt marshes. Within the Wadden Sea system there is a diversity of tidal flats with sediment of different silt content and different exposure times.

Biological processes both respond to and affect pattern diversity, geomorphological processes and sediment characteristics. Typical structures of biogenic origin can develop on the tidal flats, such as oyster and mussel beds, reefs of tube building polychaetes, eelgrass fields, burrows and tubes of digging polychaetes or mats of microphytobenthos. Biogenic habitat transformations result (Reise, 2002). Reefs of suspension feeders increase bed roughness and actively filter suspended particles, accumulating these in the bed and leading to a raised and stabilized bed. Eelgrass meadows slow down flow, protect the bed from erosion and trap suspended particles, raising the bed. The reworking of the bed by infauna changes the sedimentary budget and composition, and making it more susceptible to erosion. Mats of microphytobenthos have a seasonal effect on bed height and silt content through excretion of polymeric substances gluing the bed particles together and thus making it more resistant to erosion. In quiet places under favourable conditions salt tolerant pioneer vegetation may develop on tidal flats. When the pioneer vegetation is succeeded by a vegetation of the next successional stage, the young, low-lying salt marsh will maintain itself by enhancing sedimentation. In a period with sea-level rise, the marsh will grow higher but if the tidal flat lags behind, cliff formation along the marsh occurs. Subsequently, the marsh will erode until new vegetation will develop on the bare gently sloping tidal flat.

All these biogeomorphological interactions can be found in and on the tidal flats of the Wadden Sea. The constantly changing conditions, the multitude of feedback systems and the very wide variety in scales make it a unique ecosystem.

Because the Wadden Sea contains many different types of islands, sheltered and exposed dunes and subsequent sheltered and exposed types of saltmarsh and green beaches there also is a great variety in vegetation types and communities. Many textbooks refer to the Wadden Sea as a strong example when describing different vegetation types. An excellent overview of vegetation types is found in Dijkema & Wolff (1983). Dijkema et al. (1984) investigated all saltmarshes along the European coasts and concluded that those bordering the Wadden Sea are of eminent importance because of their size and completeness.

Dense concentrations of animals, whether forming biogenic structures or not, may form specific communities. More than 125 years ago the community of an oyster reef in the Wadden Sea was described and the term '*BIOCOENOSIS* was introduced (Möbius, 1877). This term is now widely used in the ecological literature, and the present day mussel beds and oyster reefs can still be regarded as prime examples.

Integrity and/or authenticity

The Wadden Sea has sufficient size to contain a functional coherence of ecosystem elements. Morphodynamic processes have relative freedom to occur. Biological processes depending on, and affecting geomorphology can be found on many scale levels, from seasonal microphytobenthos mats gluing the sediment together to saltmarshes raising the sediment level and growing with sea level rise. Anthropogenic influences are well regulated, a set of ecotargets is internationally agreed on (Esbjerg declaration) and monitored to safeguard the integrity. Rehabilitation measures are being carried out, for example on mussel beds. Up to the seventies mussel beds covered extensive parts of the tidal flats, filtering the water above and producing faecal pellets that sink to the bed. As a result, these beds capture fine sediments and prevent erosion. Due to over fishing these beds have almost disappeared, but rehabilitation measures seem to work out well (Dankers et al., 2003, 2004., De Vlas et al., 2005).

The present status of the system is well described by Essink et al. (2005) in the most recent Quality Status Report (QSR), and possible threats are given by Nordheim et al (1996) and Ssymanck & Dankers (1996).

Protection and management

The protection status of the Wadden Sea is sufficient to keep the system in its present state, but more conservation efforts are required in order to reach a favorable conservation status as required by the EU- Bird and Habitat directives. These measures are laid down in many agreements and European and national legislation.

Comparative analysis

The Wadden Sea forms an outstanding example of biogeomorphological interactions on all scale levels. The features of shallow productive mud flats, strong benthic-pelagic coupling and interactions between biology and morphology can be found in other estuaries, but not on the scale and the completeness of the Wadden Sea. The closest resemblance has the Banc d'Arguin in Mauritania. Its total size is larger than the Wadden Sea (12,000 km^2), but half of it is terrestrial and it has much less intertidal area (540 km^2). Furthermore, it is located in an entirely different biogeographical region, it does not have barrier islands and has very sheltered regions. In fact, the comparative analysis in the nomination dossier of the Parc national du Banc d'Arguin does not even consider the Wadden Sea as a comparable area.

There is no similar area in northern latitudes to be found. The Ria Formosa is of a much smaller size, not containing similar dune and saltmarsh systems, while there also is a lack of very silty parts. The barrier systems of North/South Carolina and Georgia (US East coast) have similar geomorphological characteristics but are very different from an ecological point of view because the intertidal flats are covered with *Spartina*, while these in the Wadden Sea are bare or partly covered by sea grasses (*Zostera* sp.). The barrier systems of Louisiana can not be compared because they have such a small tidal range that the majority of the sandbanks are permanently covered by the sea.

3 Criterion x

"contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation"

The Wadden Sea is extremely rich in environmental gradients and transitional zones, yielding many different (micro)habitats. This forms the basis for exceptional species diversity. The saltmarshes host about 2,300 species of flora and fauna. The marine and brackish areas count even 2,500 species. As a result of the many different microhabitats, there is a high degree of ecological specialization.

a) Fish

The shallow environment of the Wadden Sea is of vital importance to the reproduction of many fish species (Berghahn, 1987). The Dutch Wadden Sea is used by 13 species that are hatched in the North Sea and use the Wadden Sea as nursery area, the Marine Juvenile species. An additional 17 species are Estuarine Resident; they live here during their entire life cycle. Furthermore, there are 10 species that use the Wadden Sea seasonally in search for food, 9 species that migrate through the Wadden Sea, 2 freshwater species and in total 45 marine visitors have been caught since 1960 (Hovenkamp & Van der Veer, 1993).
The Wadden Sea is, therefore, indispensable for a much wider area comprising large parts of the North Sea. Since there is an active exchange of fish between the North Sea and the Wadden Sea, population dynamics of North Sea fish species can drive ecological processes in the Wadden Sea.
The Wadden Sea is important to migratory fish. It gives an open connection between large rivers, such as Eems & Elbe, and the North Sea. The following fish species are (or were in case of the sturgeon) found in the Wadden Sea and are listed on the IUCN Red List:

Species	*Common name*	*IUCN Red List status*
Acipenser sturio	Common sturgeon	CR A2d
Alosa alosa	Allis shad	DD
Alosa fallax	Twait shad	DD
Coregonus oxyrinchus	Houting	DD
Lampetra fluviatilis	River lamprey	LR/nt
Raja clavata	Thornback skate	LR/nt

Restoration of smooth salinity gradients in open connections with (small) rivers might improve conditions for these migratory species.

b) Marine mammals

On top of the benthic and pelagic food chain, marine mammals depend on the large productivity of the Wadden Sea. Four species are inhabitants of the Wadden Sea: Harbour seal (or Common seal), Grey seal, Harbour porpoise and Bottlenose dolphin.

Harbour seals in Europe belong to a distinct sub-species (*Phoca vitulina vitulina*) which is found mainly in UK, Icelandic, Norwegian and Wadden Sea waters. The international Wadden Sea holds approximately 20% of the world-population (some 20,000 individuals). Samples from seals in Northern Ireland, the west and east coasts of Scotland, the east coast of England, the Dutch and German Wadden Sea, the Kattegat/Skagerrak, Norway, the Baltic Sea and Iceland have been subjected to genetic analysis. This analysis suggested that there are genetically distinct common seal populations in European waters (Goodman, 1998). There is probably very little movement of breeding animals between these populations.

A unique feature of the Wadden Sea Harbour seals is that they rely on the Wadden Sea tidal sandflats for resting. Their resting habitat disappears during high tide and therefore, their behaviour is completely adapted to these conditions. There's one other location where this is found, The Wash (UK), however an insignificant number of seals are situated here. All other Harbour seal habitats consist of rocky shores.

Grey seals (*Halichoerus grypus*) are found across the North Atlantic Ocean and in the Baltic Sea. There are three regional populations. One in the Northwestern Atlantic; in Canada, on Nova Scotia and the Gulf of StLawrence, one in the Northeastern Atlantic; Iceland, UK, Wadden Sea, and a Baltic population.
The number of Grey seals in the Wadden Sea is steadily increasing. In 2006, a number of 1786 animals have been observed in the Dutch Wadden Sea (Reijnders, pers. comm.). This is however, a small percentage compared to the number of Grey seals in British waters, which counts approximately 120,000 individuals.

Harbour Porpoise (*Phocoena phocoena*) is a typical coastal species. It is mainly found in a wide area of the North Atlantic (including North Sea) and North Pacific. The most important calving and nursing site of the central North Sea is off the coast of the Wadden islands Sylt and Amrun (Sonntag et al., 1999). The Wadden Sea itself is not essential to the survival of this species, but is extensively used around March, when Harbour porpoise hunts for adult Herring that enters the Wadden Sea (Leopold, pers. comm.). The numbers of sightings along the Dutch coast are increasing significantly from 2000 onwards and porpoises are regularly observed in the Wadden Sea (Camphuysen & Peet, 2006).

Species	*Common name*	*IUCN Red List status*
Phocoena phocoena	Harbour porpoise	VU A1cd

Bottlenose dolphin (*Tursiops truncates*) is a typical coastal species as well. They reside along the southern North Sea coasts and were frequent visitors of the Wadden Sea until the Zuiderzee was closed off (1932). In recent years their presence is infrequent, although in 2004 large groups (tens to hundreds) were seen entering and leaving the Wadden Sea through the Marsdiep at Texel (Camphuysen & Peet, 2006).

Species	*Common name*	*IUCN Red List status*
Tursiops truncates	Bottlenose dolphin	DD

c) Migratory birds
The value of the Wadden Sea to migratory birds is eminent. A maximum of some 6.1 million birds are present in the international Wadden Sea *at the same time* (Blew & Südbeck, 2005). Each year on average 10 to 12 million birds migrate back and forth between their breeding grounds in Siberia, Scandinavia, Greenland and North-East Canada and their wintering grounds in Europe and Africa. These birds use the Wadden Sea for a short stay, as a major stop-over site for refueling or as a wintering area (Meltofte et al., 1994).

Figure 4. Important areas for waders along the East-Atlantic flyway. (1) Wadden Sea (2) Banc d'Arguin, Mauritania, (3) Bijagos Archipelago, Guinea-Bissau, (4) French tidal flats, (5) UK estuaries.

Fig. 4 shows the important areas for waders along the East-Atlantic flyway. The southernmost area that is important for waders is the Bijagos Archipelago in Guinea-Bissau. This is an estuarine area with tidal flats and mangroves, covering 1570 km^2 (Zwarts, 1988). More to the north lies the Banc d'Arguin in Mauritania. This has a rather small intertidal area of approximately 535 km^2, including sebkhas and small areas covered with *Spartina* and mangroves (Hagemeijer & Smit, 2004). This is considerably smaller than the Wadden Sea, which has a total size of 9,500 km^2 of which 4,534 km^2 consists of intertidal flats (Meltofte et al. 2004). The Banc d'Arguin is the most important wintering ground and most birds that migrate to their breeding grounds up north make a stop-over in the Wadden Sea, especially those breeding in Scandinavia and on the Siberian tundras. The Wadden Sea itself is an irreplaceable stop-over on the migratory flyway. Apart from the Wadden Sea, various small Moroccan, Portuguese and French tidal flats may serve a role as "pit stop", especially during unfavourable weather conditions (northern wind) and so does the southwest of the Netherlands, but these are of insufficient size to host the whole population for an extended period of time (Smit & Piersma, 1989, Reneerkens et al., 2005).

The importance for migrating birds is of outstanding universal value from the point of view of conservation. For at least 52 geographically distinct populations of 41 bird species, more than 1% of the biogeographical population occur in the Wadden Sea. All in all, this means that a very special international responsibility of the Wadden Sea has to be stated for these populations and species (Meltofte et al., 1994; Rasmussen et al., 1996).

Meltofte et al. (1994) give an excellent overview of the international importance[1] of the Wadden Sea for birds:

Gulls and terns

Among gulls and terns, the Wadden Sea is of international importance for at least nine populations. Most of these also breed in internationally important numbers.

Ducks and geese

An estimated 2.0-2.5 million ducks and geese visit the Wadden Sea during the year. For 11 populations of waterfowl the area is of international importance. Almost the entire population of "Russian" Barnacle Goose *Branta leucopsis* and Dark-bellied Brent Goose *Branta b. bernicla* use the Wadden Sea. Largest waterfowl numbers occur in late autumn, when more than 1 million are regularly present. Wigeon *Anas penelope*, Shelduck *Tadorna tadorna* and Eider *Somateria mollissima* are most numerous. For the two latter species, the Wadden Sea is the most important moulting area for the north European populations.

Waders

An estimated 6-7 million waders visit the Wadden Sea each year. For about 30 populations of West Palearctic and Nearctic waders (20 species of coastal as well as inland waders) the area is of international importance, and in 12 of these more than half of the population occurs in the Wadden Sea. Almost the entire flyway populations of Grey Plover *Pluvialis squatarola*, Siberian Knot *Calidris c. canutus*, West Palearctic Dunlin *Calidris a. alpina* and Bar-tailed Godwit *Limosa lapponnica* visit the area each year.

Almost the entire population of the Dark-bellied Brent Goose and the entire North-European population of Dunlin use the Wadden Sea during several periods of their annual cycle (Blew & Südbeck, 2005). In addition, the Wadden Sea and the coastal zone of the adjacent North Sea are used by high numbers of moulting and feeding common eider and support the entire Northwest-European population of Common Shelduck during moult in summer. Without the Wadden Sea their populations would suffer heavily.

Moreover, for in total 34 species, the nutritious tidal flats and salt marshes are an indispensable stopping place on their migration route, or form their primary wintering or moulting habitat. Therefore the Wadden Sea can be considered essential for the existence of these species. A severe deterioration of the Wadden Sea implies a biodiversity loss on a world-wide scale. This applies primarily for the following 34 species (Blew & Südbeck, 2005):

1. Great Cormorant
2. Eurasian Spoonbill
3. Dark-bellied Brent Goose
4. Barnacle Goose
5. Common Shelduck
6. Eurasian Wigeon
7. Common Teal
8. Mallard
9. Northern Pintail
10. Northern Shoveler
11. Common Eider
12. Eurasian Oystercatcher
13. Pied Avocet
14. Great Ringed Plover
15. Kentish Plover
16. Eurasian Golden Plover
17. Grey Plover
18. Northern Lapwing
19. Red Knot
20. Sanderling
21. Curlew Sandpiper
22. Dunlin
23. Ruff
24. Whimbrel
25. Bar-tailed Godwit
26. Eurasian Curlew
27. Spotted Redshank
28. Common Redshank
29. Common Greenshank
30. Ruddy Turnstone
31. Black-headed Gull
32. Common Gull
33. Herring Gull
34. Great Black-backed Gull

[1] An area is considered internationally important when more than 1% of a biogeographical population frequently is present in that area. The term internationally important originates from the Ramsar Convention and has been widely used since then in many international agreements and publications.

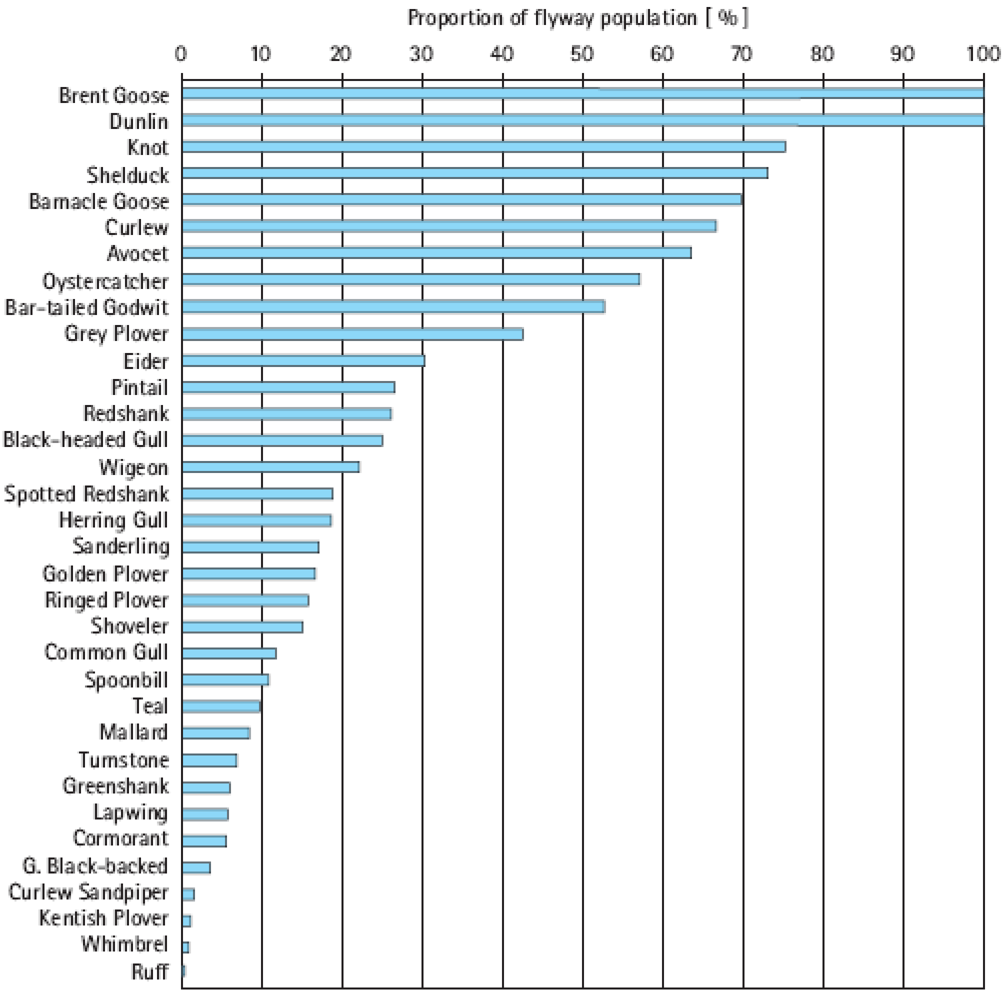

Figure 5. Maximum estimated numbers of migratory birds between 1992-2000 given as proportion of flyway populations (Wetlands International, 2002) for the entire Wadden Sea. From: Blew & Südbeck (2005).

d) Breeding birds

21 breeding bird species occur in the Wadden Sea at internationally important levels (at least 1% of the NW-European population). Many of these species (9) are also included in Annex I of the EC Birds Directive and deserve as such special protection. Another four species breed in rather low numbers in the Wadden Sea, but are included in Annex I as well (Ruff *Philomachus pugnax*, Little Gull *Larus minutus*, Mediterranean Gull *Larus melanocephalus* and Short-eared Owl *Asio flammeus*). In an international context, the Wadden Sea is a core breeding area for Eurasian Spoonbill, Avocet, Gull-billed Tern and Sandwich Tern. For each of these species more than 25% of the NW-European population breeds in the Wadden Sea area (Koffijberg et al., 2006), Figure 6.

One of the breeding birds, the Black-tailed godwit, is found on the IUCN Red List. It has 4% of the NW-European population in the Wadden Sea, mainly the Dutch part.

Species	*Common name*	*IUCN Red List status*
Limosa limosa	Black-tailed Godwit	NT

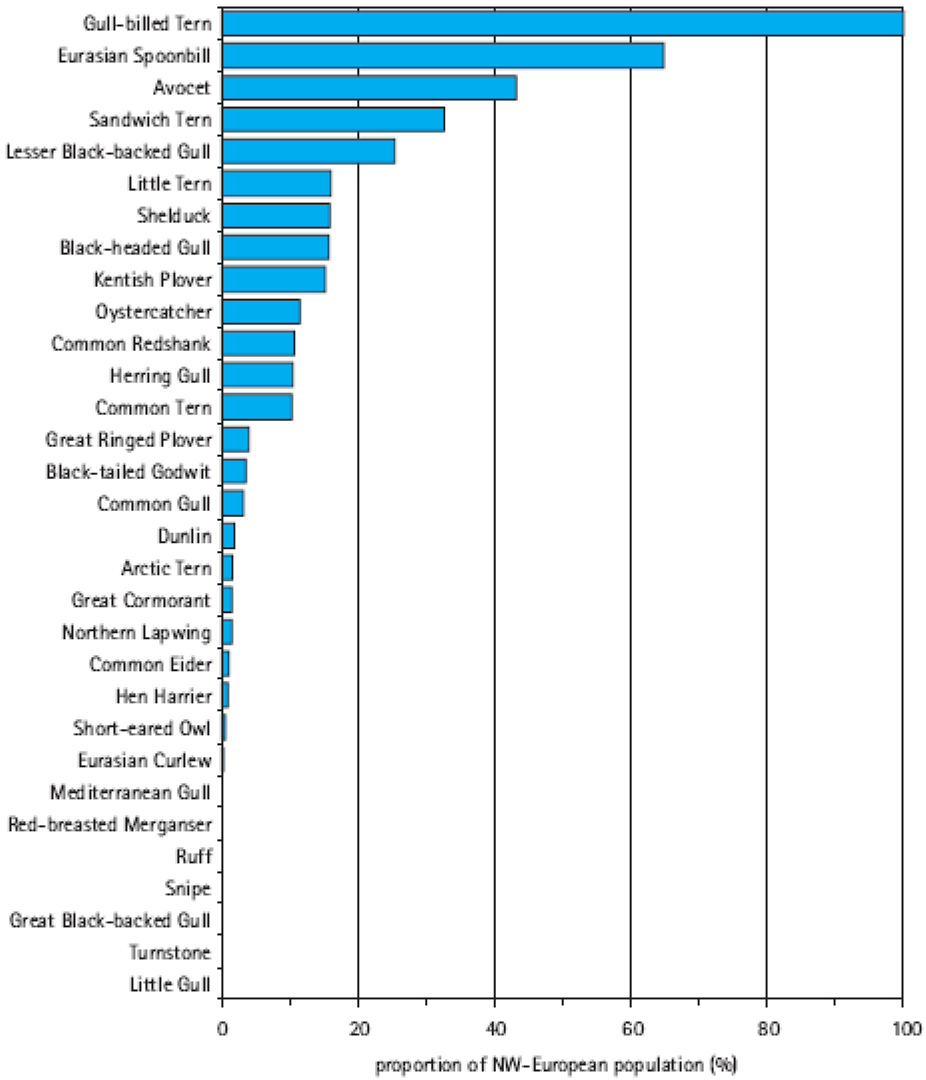

Figure 6. Comparison of breeding bird populations in the Wadden Sea in 2001 with NW-European population sizes given by BirdLife International (2004) and Thorup (2006, waders only). From: Koffijberg et al. (2006).

Integrity and/or authenticity
Although bird migration is a global natural phenomenon that cannot be associated to a single site, the Wadden Sea is a vital and irreplaceable stepping stone that is considered a critically important 'mega-site' for bird migration. It is not just one of several stopover sites on the East-Atlantic flyway, but it is *the* essential stopover.

Because of the size, the length and the different conservation regimes most of the natural ecotopes of a barrier island saltmarsh and tidal flat system still exist. Especially the mutual dependency of ecotopes and completeness of an entire system can be found in the Wadden Sea. The quality of the area for migrating birds also is partly the result of the large size, which makes it easier to flee to other parts of the area when locally the conditions are less optimal.

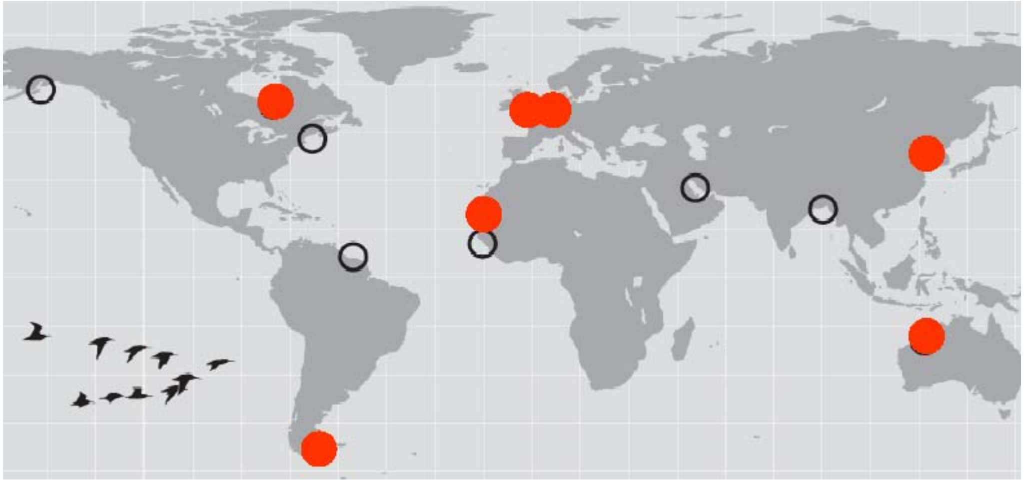

Figure 7. Important and large wadden areas, filled circles represent areas where shellfish are an important food source (after Van de Kam et al., 1999).

Protection and management
The protection status of the Wadden Sea is laid down in many agreements and European and national legislation.

Comparative analysis
The Wadden Sea belongs to the largest wadden areas in the world. Although wadden areas occur in more locations around the world (Fig. 6), most of them have a distinctly different character.

The international Wadden Sea is, with 490,000 ha of tidal flats, by far the largest of Europe. It is 16 times larger than the second largest (Morecambe Bay, UK, 33,700 ha). Its area is even one and a half times larger than all the intertidal areas in the 155 British estuaries together. Apart from Morecambe Bay, the larger ones are the Wash (29,800 ha), the Solway Firth (24,600 ha), the Severn (16,900 ha), the Dee (13,000 ha), the Humber (13,500 ha) and the Thames (totalling 25,500 ha of smaller areas). Other large wadden areas in more or less temperate regions can be found along the East coast of Canada (Bay of Fundy, Hudson Bay), in Alaska (Copper River Delta), in East Asia (Yellow Sea), and West Asia (Persian Gulf). In tropical regions large areas are found in West-Africa (Guinea Bissau and Mauritania), South-East Asia (China, Vietnam and Irian Jaya), Northwest Australia and in Suriname (Van de Kam et al., 1999).

The Wadden Sea climate cannot be compared to those in tropical or arctic regions. Apart from that, the character of the Wadden Sea, having a tidal flat and barrier-island system, is of outstanding universal value.

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has been produced with great care. The scientific quality has been peer-reviewed by Prof. Dr. Karsten Reise, Alfred Wegener Institute, Germany and assessed by or on behalf of the Scientific Board of Wageningen IMARES.

Dr. H.J. Lindeboom

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