OSPAR COMMISSION

# Background Document for Intertidal mudflats

Biodiversity Series

2009

### OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the “OSPAR Convention”) was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

### Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l’Irlande, l’Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d’Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l’Espagne.

## Acknowledgement

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# Contents

# Background Document for Intertidal mudflats

## Executive Summary

This background document on Intertidal mudflats has been developed by OSPAR following the inclusion of this habitat on the OSPAR List of threatened and/or declining species and habitats (OSPAR agreement 2008-6). The document provides a compilation of the reviews and assessments that have been prepared concerning this habitat since the agreement to include it in the OSPAR List in 2003. The original evaluation used to justify the inclusion of Intertidal mudflats in the OSPAR List is followed by an assessment of the most recent information on its status (distribution, extent, condition) and key threats prepared during 2008-2009. Chapter 7 provides recommendations for the actions and measures that could be taken to improve the conservation status of the habitat. On the basis of these recommendations, OSPAR will continue its work to ensure the protection of Intertidal mudflats, where necessary in cooperation with other organisations. This document may be updated to reflect further developments.

## Récapitulatif

Le présent document de fond sur les *vasières intertidales* a été élaboré par OSPAR à la suite de l'inclusion de cet habitat dans la liste OSPAR des espèces et habitats menacés et/ou en déclin (Accord OSPAR 2008-6). Ce document comporte une compilation des revues et des évaluations concernant cet habitat qui ont été préparées depuis qu'il a été convenu de l'inclure dans la Liste OSPAR en 2003. L'évaluation d'origine permettant de justifier l'inclusion des *vasières intertidales* dans la Liste OSPAR est suivie d'une évaluation des informations les plus récentes sur son statut (distribution, étendue et condition) et des menaces clés, préparée en 2008-2009. Le chapitre 7 recommande des actions et mesures à prendre éventuellement afin d'améliorer l'état de conservation de l'habitat. OSPAR poursuivra ses travaux, en se fondant sur ces recommandations, afin de s'assurer de la protection des *vasières intertidales*, le cas échéant en coopération avec d'autres organisations. Le present document pourra être actualisé pour tenir compte de nouvelles avancées.

## 1. Background Information

### Name of habitat

Intertidal mudflats

### Definition of habitat

Two sub-types:

- Marine intertidal mudflats
- Estuarine intertidal mudflats

The agreed OSPAR habitat working definition is as follows: "Intertidal mud typically forms extensive mudflats in calm coastal environments (particularly estuaries and other sheltered areas), although dry compacted mud can form steep and even vertical faces, particularly at the top of the shore adjacent to salt marshes. The upper limit of intertidal mudflats is often marked by saltmarsh, and the lower limit by Chart Datum. Sediments consist mainly of fine particles, mostly in the silt and clay fraction (particle size less than 0.063 mm in diameter), though sandy mud may contain up to 80% sand (mostly very fine and fine sand), often with a high organic content. Little oxygen penetrates these cohesive sediments, and an anoxic layer is often present within millimetres of the sediment surface. Intertidal mudflats support communities characterised by polychaetes, bivalves and oligochaetes. This priority habitat has been divided into two sub-types, based on the predominant salinity regime."

Mudflats are highly productive areas which support large numbers of birds and fish. They provide feeding and resting areas for internationally important populations of migrant and wintering waterfowl, and during neap low tides provide the only readily available food source. At high tide they are important nursery areas for flatfish. The most important marine predators on intertidal sand and mudflats are particularly the flatfish *Solea solea* (sole), *Limanda limanda* (dab), *Platichthys flesus* (flounder) and *Pleuronectes platessa* (plaice) which feed on polychaetes, bivalves and tidally active crustaceans. In summer, large numbers of plaice and dab juveniles move over flats at high tide to feed on mobile epifauna, sedentary infauna and protruding siphons and tentacles. Within estuaries and on mud and sandflats, however, many demersal fish are opportunistic predators and the prey choice will reflect the infaunal species distribution of the area (Elliott, 1998).

This OSPAR habitat is closely linked to several other OSPAR habitats as biogenic structures can form on top of the flats: Vast areas of the Wadden Sea intertidal mudflats are colonised first by mussels (although strictly speaking the OSPAR habitat Mytilus beds is restricted to mixed and sandy sediment). Recently many beds are invaded by the pacific oyster *Crassostrea gigas*, the slipper limpet *Crepidula fornicata.* The European flat oyster *Ostrea edulis* and seagrass *Zostera sp.* beds can also colonise this habitat. This ecological patchwork is rivalled in complexity by many overlapping sector regulations as estuarine mudflats in particular are at the interface of land, freshwater and seawater habitats. All these factors render intertidal mudflats as very difficult to classify: they lie somewhere between outstanding and everyday nature in a no man's land to which no endemic species belong with a low biodiversity, yet paradoxically harbour a very high biological productivity and abundance of invertebrate species.

## 2. Original Evaluation against the Texel-Faial selection criteria

### List of OSPAR Regions where the feature occurs

I, II, III, IV

Dinter biogeographic zones: 4 (Warm temperate pelagic waters), 6-9 (Lusitanean, Lusitanean-boreal, Cold temperate pelagic waters and boreal lusitanean waters), 11(Boreal)

### List of OSPAR Regions and Dinter biogeographic zones where the habitat is under threat and/or in decline

As above

### Original evaluation against the Texel-Faial criteria for which the habitat was included on the OSPAR List

Intertidal mudflats were selected for inclusion on the OSPAR list on the basis of an evaluation of their status according to the Criteria for the Identification of Species and Habitats in need of Protection and their Method of Application (the Texel-Faial Criteria) (OSPAR 2003). The nomination for inclusion on the list cited the criteria decline, sensitivity and ecological significance, with information also provided on threat. Table 1 provides an update on this evaluation. The main threats to this habitat are land claim for agricultural and industrial use, effluent discharges, oil spills, dredging, (shellfish)fishing, bait digging and sea level rise.

**Table 1:** Summary assessment of intertidal mudflats against the Texel-Faial criteria

| Criterion | Comments | Evaluation |
|---|---|---|
| Global importance | A habitat present anywhere with sheltered gently-sloping seabeds and medium to large tidal ranges. They occur predominantly in estuaries and the adjacent sedimentary coastal areas, in sheltered marine bays and semi-enclosed areas behind barrier islands including lagoons. As such they are amongst the most widespread marine and estuarine habitats and cover areas from a few hectares to several square kilometres within a site and several times this within any geographical area (Elliot, 1998). The Wadden Sea is the largest European wetland area and its tidal flats form the largest unbroken stretch of mudflats worldwide (CWSS 2008). The UNESCO World Heritage Committee (WHC) adopted the statement on the "outstanding universal value" of the Wadden Sea in June 2009 and inscribed the Dutch-German Wadden Sea on the World Heritage List (WHC, 2009, Decision 33 COM 8B.4) | Does not qualify |
| Regional importance | The largest continuous area of intertidal mudflats in the OSPAR area is in region II bordering the North Sea coasts of Denmark, Germnay and the Netherlands in the Wadden Sea and covering around 470,000ha (OSPAR, 2006). The Wadden Sea has an intertidal sand and mudflat area of 4700 km² (CWSS 2008) -twice the amount of all British areas put together. However there are untold numbers of shallow bays, estuaries and inlets along the North Sea, English Channel and Atlantic Coast which also harbour this habitat in all four of the OSPAR regions where it occurs | Does not qualify |
| Rarity | Intertidal mudflats occur predominantly in estuaries and the adjacent sedimentary coastal areas, in sheltered marine bays and semi-enclosed areas such as behind barrier islands. As such they are amongst the most widespread marine and estuarine habitats and cover areas from a few hectares to several square kilometres within a site and several times this within any geographical area (Elliott, 1998). The Wadden Sea is unique in that it consists entirely of a sandy-muddy tidal system with only minor river influences on morphodynamics. It differs from other systems of this type in that it is the only tidal flat and barrier island depositional system of this scale and diversity in the world (CWSS 2008). Other large stretches of intertidal flats often have a riverine depositional history | Does not qualify |
| *Sensitivity* | The findings from various studies on the sensitivity of this habitat have been brought together in a review by Elliot (1998). Both mudflat sub-types are naturally resilient and can recuperate well from isolated physical and chemical disturbances, although Bernem & Lübbe (1997) consider intertidal flats to be very sensitive to oil pollution as the oil enters lower layers of the mudlflats where lack of oxygen prevents decomposition of the oil.<br>However once the habitat disappears, due to agricultural land reclaim, infrastructure development or saltmarsh growth, the process is irreversible. | *Does not qualify* |

| | | |
|---|---|---|
| Ecological significance | Intertidal mud flats are important in the functioning of estuarine systems and may have a disproportionately high productivity compared to subtidal areas (Elliott, 1998). Intertidal mudflats have a low species diversity but huge overall invertebrate productivity, resulting in an important and perpetually exploited food source for waders, waterfowl and fish. At low tide they provide feeding and resting areas for internationally important populations of migrant and wintering waterfowl, whereas at high tide they are also important nursery areas for flatfish and feeding grounds for numerous fish species.<br>Intertidal areas dissipate wave energy, thus reducing the risk of eroding saltmarshes, damaging coastal defences and flooding low-lying land. The mud surface also plays an important role in nutrient chemistry. In areas receiving pollution, organic sediments sequester contaminants and may contain high concentrations of heavy metals. | Qualifies |
| Decline | Reduction in the area of intertidal mudflats has occurred in many parts of the OSPAR area and is particularly alarming for estuarine intertidal mudflats which are favoured for land claim. The prolific spread of the cordgrass *Spartina anglica* is one of many factors decreasing intertidal mudflat areas by colonising its upper limits. A saltmarsh by definition is an intertidal mud or sand flat that has been colonised by salt tolerant (halophytic) vegetation. Thus, saltmarshes and mudflats are a linked continuum of intertidal habitats (Atkinson, 2001). Estuarine mudlflats naturally progress towards marsh areas over time, but this process is much accelerated by anthropogenic influences.<br>A reduction in the area and biological integrity of intertidal mudflats will reduce their carrying capacity for supporting bird and fish predator populations (OSPAR, 2006). Industrialised areas are often subject to a variety of pressures such as degradation through high levels of pollution and waste discharge. | Declined |

# 3. Current status of the species or habitat

### Distribution in OSPAR maritime area

Figure 1 shows intertidal mudlflat records compiled from the September 2008 version of the OSPAR GIS system (http://www.searchnbn.net/hosted/ospar/ospar.html). Several countries did not submit shapefiles therefore the absence/presence depicted is inaccurate. In particular gaps are expected along the coasts of Spain and Portugal. A more detailed map of the Wadden Sea is provided in Annex 3.

### Habitat extent (current/trends/future prospects)

This habitat is present in a vast number of estuaries bays and inlets in the OSPAR maritime area, each with their own specific environmental and managemental conditions. The full extent of this habitat and its loss in extent over time is not fully documented for most Contracting Parties. Therefore a case study of the intertidal mudflats of the Seine estuary in France has been chosen to illustrate the wide range of ecological and industrial functions this habitat represents.

The Seine estuary is the largest megatidal estuary in the English Channel, covering about 150 $km^2$ at high tide (Dauvin & Desroy, 2005), with 25% of the French population and 40% of her industry and agriculture concentrated along either bank. Like many European rivers, the Seine River and estuary was nearly entirely channelised at the beginning of the Century to enhance agricultural use of the rich alluvial soils, secure river navigation, and prevent flooding (Chaberie *et al.,* 2001). Since the mid-19th century, industrial activity and development has taken place in the lower part of the Seine, which has been canalised and dredged 120 km upstream from the mouth to allow navigation from the sea to the inland port of Rouen. At the mouth, intensive dredging is necessary to maintain water depth at 5–6 m below the zero sea level. Due to the

successive construction of dykes, the intertidal zone had been reduced from 130 km$^2$ at the middle of the 19th century to <30 km$^2$ in 2000 (Figure 2). Nowadays, intertidal mudflats and salt marshes are restricted to the northern bank of the estuary, and muddy sand is found only in the South Channel downstream from Honfleur.

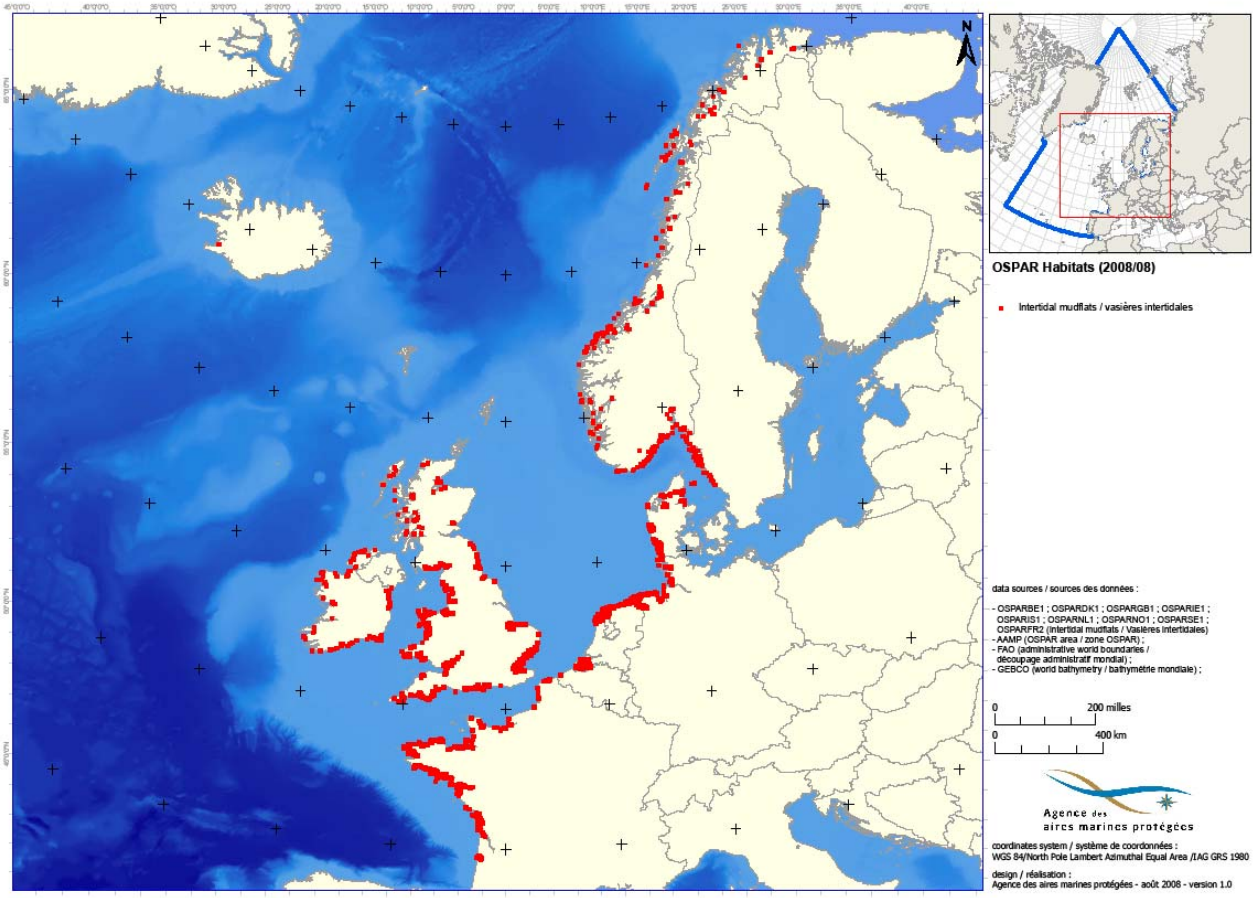



**Figure 1:** Preliminary distribution of intertidal mudflats in the OSPAR maritime area (based on data supplied by Contracting Parties up to the JNCC up until September 2008).

Over the last two centuries, the restriction of the volume of the Seine estuary brought about a shift from an unfilled natural estuary to a pipe-like design, where the silt-clay material passes through or is temporarily accumulated. The decrease in the estuary's volume was originally natural; however as a result of a combination of civil engineering works, infilling of the upstream part of the estuary, and silting up, the natural sedimentation process has been considerably accelerated by human activity. Nevertheless, the lower part of the Seine estuary has kept its important biological functions and remains very productive despite being highly partitioned. The intertidal mudflats on the northern estuary bank remain an important nursery for marine fish like the sea bass and the sole, and the Seine estuary maintains its attractiveness for wildlife, despite industrialisation and land-claim, because estuarine habitats are the most resilient habitats on earth (Elliott & McLusky, 2002).

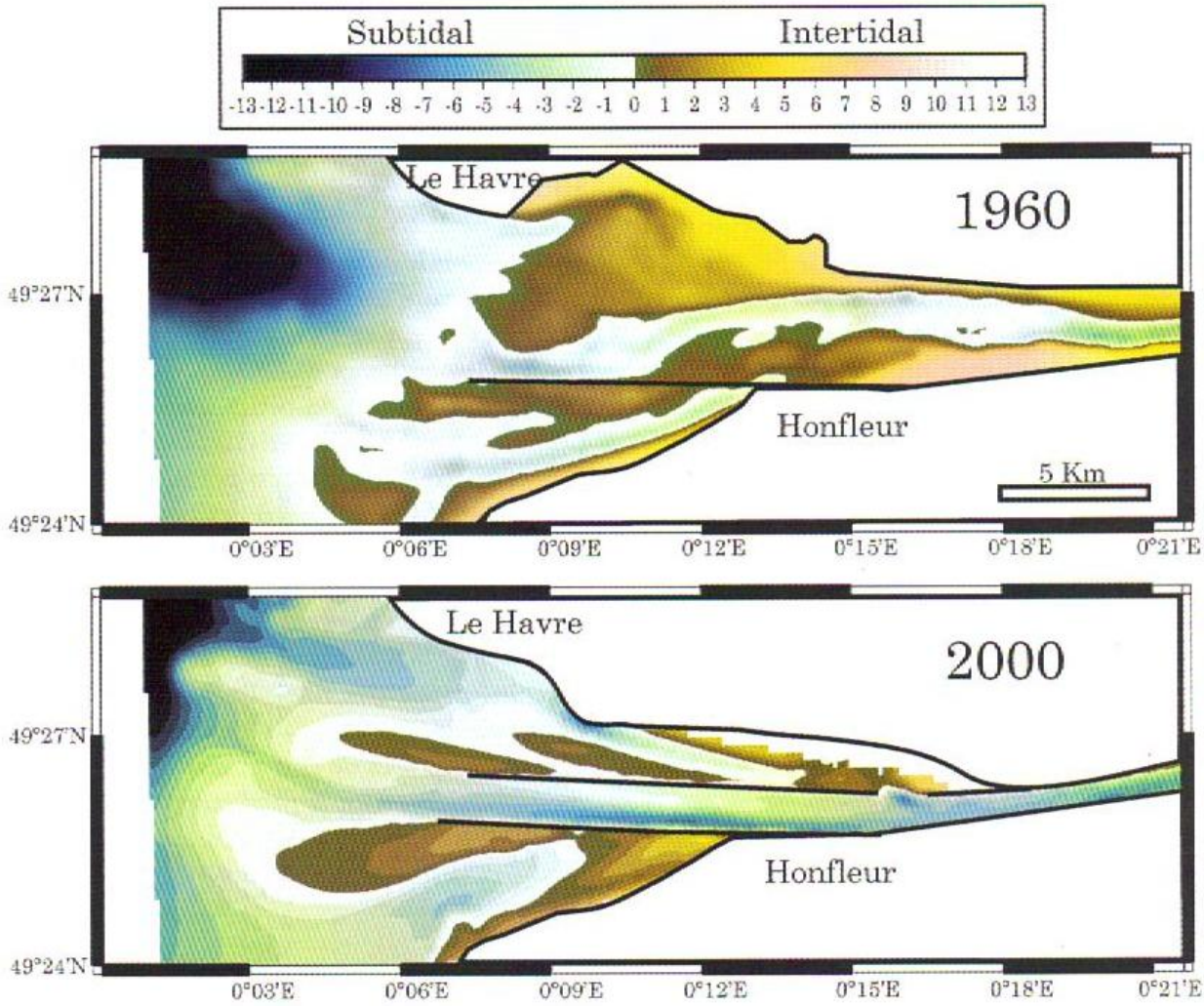



**Figure 2** (in Dauvin *et al.*, 2002): The temporal evolution of the Seine estuarine mudflats, showing the large decrease in their surface area. Bathymetric data from the inland port of Rouen.

In 1990, an artificial intertidal mudlflat of 21ha was created as a mitigation measure in order to "balance" the construction of the Bridge of Normandy. This was an experimental first in Europe and research on the durability of these mudlflats were carried out until 1995. After 4 years of surveying the study concluded that the artificial estuarine mudflat was a highly productive yet unstable environment. The functional characteristic of artificial mudflats would be rapidly lost without regular maintenance, as the natural dynamics cannot be recreated and the mudflats, unless the channels are artificially maintained by dredging, are colonised very rapidly by saltmarshes (Dauvin *et al.*, 2002). Artificial mudlflats and other compensatory measures are therefore not a viable compensation for rampant urbanisation, and can in fact be more detrimental than beneficial for conservation purposes as they provide an alibi for the acceptance of industrial management and the destruction of the surroundings (Desroy *et al.,* 2004).

The concept of sustainability seeks to establish a consensus between widely diverse points of view – flood defense, navigation, water quality, conservation and recreation – in an attempt to balance the economic, social and environmental considerations that will result in a solution that satisfies everyone. In this context, the Seine estuary, like other estuaries, presents a daunting challenge for legislators,

territorial planners and the scientific community as they struggle to formulate plans for future estuarine management (Dauvin & Desroy, 2005).

Extensive areas of intertidal mud and sandflats have been removed through land-claim coupled in some areas with rising relative sea-levels (Elliott, 1998). Some estuaries have lost up to 80% of the available area, most of which has been the land claim of intertidal mud and sand flats. In addition, sea level rise and the constraining of the upper shore boundary will produce 'coastal squeeze'. Hence there is increasing potential for conflict arising from the conservation interests and the use of estuaries and other coastal areas by people for coastal defence, recreational and many other purposes.

### Condition (current/trends/future prospects)

After 10 centuries of land reclamation on the sea, Western Europe prudently launched the science of intertidal habitat creation or restoration (de-polderisation or managed retreat) during the 1980s.Deliberate restoration of land to the sea has from that time on had a growing effect, . A study by Goeldner-Gianella (2005) identified 30–40 schemes on the British and European coasts (Figure 3 ), where the total combined surface area was no more than a few dozen square kilometres (i.e., less than 1% of the 15,000 km2 of tidal polders in all of Europe), although this study cannot in itself be considered exhaustive. Anticipated projects are also more numerous in Britain than on the continent (Figure 3) (Goeldner-Gianella, 2005), however they rarely exceed 100ha in size and the total restoration area of these 48 sites (2007 ha) is lower than that of the ten German sites (2590 ha) (Wolters *et al.,* 2005), although three of the schemes presented in figure 3 for the German coast (Beltringharderkoog, Speicherkoog & Rantumbecken on the island of Sylt) are not de-polderisation schemes but embankment schemes (Fleet, *pers. comm*.). Along the Wadden Sea coast, the main reason for de-embankments is habitat restoration. In the Netherlands well-described and studied examples on which monitoring continues occur at Noord Friesland Buitendijks (Norberts, pers. comm).

In the majority of UK studies listed in an English Nature research report (Atkinson *et al.*, 2001), the design of monitoring schemes and the definition of success criteria have been inadequate to determine whether a created or restored wetland has reached its intended target. Monitoring and assessment is an important component in the mitigation/compensation process and there are no agreed protocols for intertidal habitat restoration. In developing such protocols, mechanisms to account for functioning at the wider landscape level (i.e.linkages between the habitat on site and those elsewhere in the coastal area), beyond individual site specific and compliance issues should be sought (Atkinson *et al*., 2001).

### Limitations in knowledge

Due to the accessibility and wide distribution of this habitat within the OSPAR region a great deal of information is available on many aspects of intertidal mudflats. However as it is still not possible to give figures for the exact extent of this habitat or its loss and condition, the collation harmonisation of existing data on this habitat must continue.


**Figure 3:**. (Goeldner-Gianella, 2007).De-polderisation schemes in Western Europe at the beginning of the 21st century.

# 4. Evaluation of threats and impacts

**Table 2:** Summary of key threats and impacts to intertidal mudflats.

| Type of pressure | Cause of threat | Comment | Scale of threat |
|---|---|---|---|
| Habitat degradation through nutrient changes | Waste: land/riverine runoff & industrial domestic effluent discharge | Diffuse and point source discharges from agriculture, industry and urban areas, including polluted storm-water run-off, can create abiotic areas or produce algal mats which may affect invertebrate communities. They can also remove embedded fauna and destabilise sediments thus making them liable to erode. The increased coverage of 'green tide' mats of opportunistic green macroalgae such as *Ulva* sp. and *Enteromorpha* sp. result in anoxic conditions below the mats. The release of refinery effluent to intertidal mudflats will result in anoxic sediments, a degraded infaunal community and changes to predator-prey relationships through a possible decrease in the palatability of prey (Elliott, 1998). Estuaries are much higher affected than coastal mudflats. | High |
| Habitat alteration through community shifts | Collecting: angling and bait digging | Fishing and bait digging can have an adverse impact on community structure and substratum and reduce biodiversity (Brown *et al.*, 1997). For example, suction dredging for shellfish, shellfish dredging, fishing or juvenile flatfish bycatch from the shrimp fisheries may have a significant effect on important predator populations. | Moderate |
| Habitat disruption and smothering | Extraction: navigational/maintenance dredging dredging for navigation, have an important effect on sediment biota and on sediment supply and transport. Worldwide, many coastal areas, including estuaries, are now either licensed or available for exploration and development, but not in areas where the EU Habitats Directive is operational. | | Moderate -Low |
| Habitat loss or alteration | Invasion by alien species | Coastal and estuarine areas are among the most biologically invaded systems in the world, especially by mollusks such as the slipper limpet *Crepidula fornicata* and the pacific oyster *Crassostrea gigas*. The two species have not only attained considerable biomasses from Scandinavian to Mediterranean countries but have also generated ecological consequences such as alterations of benthic habitats and communities, or food chain changes. In the Wadden Sea around 50 non-indigeneous species are present, but the main issues of concern are the pacific oyster (*Crassostrea gigas*), which has also spread in the Thames estuary and along French intertidal flats.The introduction of new or non-native plant species also alters the habitat, for example the spread of cord-grass *Spartina anglica* which has vegetated some upper-shore mudflat areas with important ecological consequences in some areas. | High |

| | | | |
|---|---|---|---|
| Habitat loss through sea-level rise | Climate change/global warming | Sea level rise is reducing the intertidal zone when sufficient sediment import is lacking. Higher sea level and increased storm frequency, resulting from climate change, may further affect the sedimentation patterns of mudflats and estuaries. A further cause for concern is the phenomenon called 'coastal squeeze'. As sea levels rise, coastal habitats such as saltmarsh, if in an entirely natural situation, would respond by moving landward or "rolling back" to adjust their position. Fixed man-made structures such as seawalls prevent or severely limit this landward movement. The coastal habitats are therefore *'squeezed out'* between rising sea levels and fixed defence lines | High |
| Habitat loss through channel modification /marsh colonisation | Barrages and reservoirs | Reduction in certain species and increased instability or changes in environmental parameters due to changed hydrophysical regime. Tidal and storm-surge barrages may lower the highwater mark, so that existing upper saltmarshes and mudflats dry and develop terrestrial vegetation. | High-localised |
| Habitat loss | Agricultural reclamation, urban & transport infrastructure | Land claim reduces the carrying capacity of the entire migration and winter feeding grounds for particular waders and wildfowl and diminishing prey levels may intensify competition and increase winter mortality rates (OSPAR, 2006). | High-land claim |
| Habitat alteration through removal of target species | Shellfish fisheries | Mussel, cockle and shrimp fisheries have either directly (through overexploitation) or indirectly (through the effects of fishing equipment on the sea bottom) been considered detrimental to the benthic community.<br>A recent study by Boucher & Sauriau (2008) on oyster culture practices on the intertidal mudflats of France's Atlantic coast shows that oyster farming alters intertidal macrozoobenthic assemblages moderately, and off-bottom cultures cause more disturbance than on-bottom cultures. Shellfish impact studies are available from the Netherlands.<br>Hydrodynamics and seasons may interact with culture practices in smothering or strengthening biodeposition-mediated effects through dispersal/accumulation of biodeposits. | Moderate |
| Pollution | Oil/tar/chemicals -hazardous substance runoff | Oil covering intertidal mud prevents oxygen transport to the substratum and produces anoxia resulting in the death of infauna (OSPAR 2006). In sheltered low energy areas pollutant dispersion will be low and the finer substrata in these areas will act as a sink. The pollutants will then enter the food chain and be accumulated by predators. Dredging and propeller wash will resuspend pollutants in the water column. | High |
| Disturbance to species | Recreational use | Human disturbance changes bird behaviour in accessible areas such as intertidal<br>mudflats. Disturbances to waterfowl in estuaries and nearshore areas includes movements by people, dogs and horses, helicopters and light aircraft, and from watersports such as windsurfing, sand yachting and boating. The intensity of disturbance is related to the species of bird and the speed and duration of the stressor and the direction in relation to bird flocks. | Low |

A reduction in the area and biological integrity of this habitat will reduce their carrying capacity for supporting bird and fish predator populations (OSPAR 2006). Land claim may reduce the carrying capacity (Goss-Custard, 1985) of the entire migration and winter feeding grounds for particular waders and wildfowl and diminishing prey levels may intensify competition and increase winter mortality rates, with a consequent effect on equilibrium population size (OSPAR 2006).

Within estuaries, mudflats deposited in the past may erode due to changed estuarine dynamics and remobilised sediment may be redeposited elsewhere in the same littoral sediment cell. Therefore it is essential that a holistic view of this habitat is considered in order to account for its high variability.

## 5. Existing Management measures

The water quality on mudflats has been regulated by a number of EC Directives including the the Urban Waste Water Treatment Directive and the Nitrates Directive, which together tackle the problem of eutrophication (as well as health effects such as microbial pollution in bathing water areas and nitrates in drinking water); the Integrated Pollution Prevention and Control Directive, which deals with chemical pollution; Dangerous Substances,  and Shellfish (Waters). The Water Framework Directive (WFD), which covers coastal waters out to 1nm from the Chart Datum limit, is particularly relevant as it aims to streamline all the above directives and integrate their objectives in a combined approach within each river basin. These commitments provide for the regulation of discharges to the sea and have set targets and quality standards covering many metals and pesticides, and other toxic persistent and bioaccumulative substances. The Programme of Measures to meet the WFD objectives will be based on the draft RBMPs (River Basin Management Plans) which are due for the end of 2009, and directly concern all intertidal mudflats.  The coastal biological quality elements (eg: macroalgae and macroinvertebrates) as well as target hydromorphology parameters as set out in this directive are particularly important for mudflats.The overall aim is for a good ecological status by 2015.

Sites designated under EU law form part of the Natura 2000 series of protected habitats, ie Special Protection Areas (SPA) under the 1979 EC Birds Directive or Special Areas of Conservation (SAC) under the 1992 EC Habitats Directive. SACs may be designated for the Annex I habitat 'Mudflats and sandflats not covered by seawater at low tide'. Mudflats are also included within several other designated Annex I Habitats: 'Estuaries', 'Lagoons' and 'Large shallow inlets and bays'. Under European law, appropriate compensation must be provided when a Natura 2000 site is adversely affected by development. Provision of compensation involves the creation or restoration of habitat of environmental value at least equivalent to that of the displaced habitat. International designations of major significance to intertidal flats are the Ramsar Convention protecting wetlands of international importance, the Bonn Convention to protect migratory species of wild animals, and the Bern Convention to conserve European wildlife and habitats (Atkinson, 2001).

Since 1978 the governments of the Netherlands, Germany and Denmark have been working jointly on the protection and conservation of the entire Wadden Sea Area, supported by the Common Wadden Sea Secretariat (www.waddensea-secretariat.org). In 1982 the countries agreed upon the Joint Declaration of the Protection of the Wadden Sea; the countries intended to coordinate their activities and measures in order to protect the Wadden Sea. A trilateral Wadden Sea Plan, adopted in 1997, focuses on: a healthy environment, diversity of habitats and species, sustainable use, integrated management, coastal protection and informing and involving the local population. The Trilateral Wadden Sea Plan (WSP)(http://www.waddensea-secretariat.org/news/documents/TGC-Stade/Stade-engl.pdf) was adopted at the Eighth Trilateral Governmental Conference in Stade in October 1997.The WSP entails the common policies, measures, projects and actions of the countries for their joint efforts to fulfill the ecological targets. Annex III of this assessment  a WSP habitat map of the Wadden Sea which shows the vast extent of the intertidal area. Seagrass beds and native blue mussel (*Mytilus edulis*) beds occupied about 2.5% of the Wadden Sea mudflats in 2004, many of these have recently

been invaded by the Pacific oyster (*Crassostrea gigas*) and the slipper limpet (*Crepidula fornicata*). More details are available in CWSS (2008) and Essink et al., (2005); a new Wadden Sea Quality Status report will be available in end of 2009.

Many international conventions that are already in place concern migratory birds (AEWA; Wetlands International IWC), which urge Contracting Parties to endeavour to give special protection to those wetlands which meet internationally accepted criteria of international importance.

## 6. Conclusion on overall status

This habitat is a hybrid and plurifunctional area, characterised by both a high ecological and economical productivity. This OSPAR habitat is readily accessible because it is at the land-sea interface and is therefore subject to a plethora of different impacts and subsequent management tools. Intertidal habitats pose special problems for restoration because (i) they are topographically and ecologically complex, (ii) they support many species of animals, some of which require specific habitats and linkages to other terrestrial or marine habitats, and (iii) they exist and evolve within dynamic coastal settings, subject to changing tidal levels, salinities and long term forcing factors associated with sea-level rise and climate change (Atkinson, 2001).

Management of both terrestrial and marine activities will be important to control factors leading to the decline and threats to this habitat type. Much of this is likely to fall under the remit of national terrestrial, urban and port planning authorities.Decisions about the location of coastal developments and improvement to water quality should be addressed by actions for Good Ecological Status in the WFD. Prater (1981) remarks, quite correctly, that land reclamation is an incorrect term used to describe the process of converting intertidal land to terrestrial land. The correct definition should really be the claiming of land as, except for on a geological time scale, intertidal mudflats were never part of the terrestrial landscape. There should be a different philosophical approach to taking something one never had from recovering that which was lost.

The future prospects of this habitat cannot be established at this time as the significance of existing site usage and the change in usage since the Habitats Directive came into force has not been ascertained. Of particular concern is urban and agricultural land claim, the encroachment of the cordgrass *Spartina anglica*, increasing development of aquaculture, the unknown extent of professional fishing and the removal of fauna. In addition, there is some concern at the potential impact that hard coastal defence structures may have in combination with seawater rise for the long-term extent of this habitat.

## 7. What action should be taken at an OSPAR level?

### Action/measures that OSPAR could take, subject to OSPAR agreement

It is proposed that OSPAR should recommend that relevant Contracting Parties take into account the need for the protection of intertidal mudlflats in the development and application of coastal defence works and infrastructure with a view to:

a. halting the erosion and pollution of intertidal mudlflats by decreasing mechanical disturbances, keeping sediment input “flowing” and improving estuarine and coastal water quality.

b. giving special protection to highly impacted areas important for the persistence of this habitat and the populations it supports.

OSPAR should require that Contracting Parties report back to the OSPAR Commission on the implementation of the above recommendations so that the development of the necessary measures can be evaluated. As a first step Contracting Parties whose coastline and estuaries harbour intertidal mudflats should make an assessment of the effectiveness of the regulations they already have in place for the protection of this habitat, consider how those regulations might be made more effective through improved monitoring, control and surveillance and report the results to the OSPAR Commission.

To complement these actions, the OSPAR Commission should:

a. communicate to the EC and the relevant authorities the need for strong development control policies to prevent development in flood risk areas, with the objective of retaining the option to use such areas for the restoration of intertidal flats if required.

b. emphasise to relevant scientific funding bodies the following research needs with respect to intertidal mudflats*:*

   (i) the need for a coherent and periodically renewed quantitative assessment of this rapidly evolving habitat at the OSPAR level

   (ii) the development of an agreed protocol for intertidal habitat restoration.

**Table 3:** Priority actions and measures which Contracting Parties should be encouraged to take

| | | |
|---|---|---|
| Key threats | Land claim for agricultural and industrial use, effluent discharges, oil spills, dredging, fishing and bait digging and sea level rise, saltmarsh encroachment. | |
| **Other responsible authorities** | EU, territorial agencies, urban, industrial and port/ shipping authorities | |
| **Already protected?**<br>**Measures adequate?** | -Habitat & Species Directive Annex II<br>-Bern Convention Annex II<br>-CMS Appendices I & II<br>-CITES Appendix I<br>-RAMSAR Convention<br>-Interreg/Life projects | A number of agreements concerning migratory should be acknowledged:<br>-AEWA (African Eurasian Waterbird Agreement)<br>-Wetlands International IWC (International Waterbird Census) |
| **Recommended OSPAR actions and measures** | Restore estuarine water quality to ensure that existing mudflats fulfil their important ecological and conservation role<br>Strengthen development and coastal protection planning policy to ensure where possible the maintenance of all active sediment sources that supply intertidal flats<br>Monitor the implementation of strong development control policies to prevent development in flood risk areas , with the objective of retaining the option to use such areas for the restoration of intertidal flats if required<br>Raise public awareness of the ecological and socio-economic value of mudflats and educate planning authorities and developers on the important functions of mudflats in estuarine and coastal systems<br>Ensure that there is no further loss of habitat, particularly in areas already subject to high loss | |

### Brief summary of monitoring system to be implemented (see annex 2)

There is a need to understand the distribution, extent and condition of this habitat including how it has changed over time, and relate this back to the range of pressures it is subject to. Member States have assessed the EC Habitats Directive Annex I habitat 1140: “Mudflats and sandflats not covered by seawater at low tide”(c.f. Annex 1), however a more common interpretation of the criteria for this assessment and hence the status of intertidal mudflats in the OSPAR area would certainly be beneficial for an overall comparable judgement.

As a first step relevant Contracting Parties should be encouraged to report to OSPAR on:

- the overall surface area, carrying capacity and-value in addition to the invertebrate communities of this habitat
- Whether each country’s impact assessment process takes account of OSPAR’s habitats, and if so can Environmental Impact Assessments’s be reported back to OSPAR. This could act as a monitoring mechanism.

An overview of the rationale and suggested monitoring techniques for this can be found in Annex 2 of this assessment.

# Annex 1: Overview of data and information provided by Contracting Parties

| Contracting Party | Feature occurs in CP's Maritime Area | Contribution made to the assessment (e.g. data/information provided) | National reports References or weblinks |
|---|---|---|---|
| *Belgium* | Y | Y | http://data.nbn.org.uk/habitat/map.jsp?HABITAT=NBNSYS0000019604 |
| *Denmark* | Y | Y | http://data.nbn.org.uk/habitat/map.jsp?HABITAT=NBNSYS0000019604<br>QSR Wadden Sea 2004, Chapter 8;<br>http://www.waddensea-secretariat.org/QSR/index.html |
| *European Commission* | Y | | |
| *France* | Y | Y | http://data.nbn.org.uk/habitat/map.jsp?HABITAT=NBNSYS0000019604 |
| *Germany* | Y | Y | http://data.nbn.org.uk/habitat/map.jsp?HABITAT=NBNSYS0000019604<br>QSR Wadden Sea 2004, Chapter 8;<br>http://www.waddensea-secretariat.org/QSR/index.html |
| *Iceland* | Y | Y | http://data.nbn.org.uk/habitat/map.jsp?HABITAT=NBNSYS0000019604 |
| *Ireland* | Y | Y | http://www.npws.ie/en/media/Media,6232,en.pdf |
| *Netherlands* | Y | Y | http://data.nbn.org.uk/habitat/map.jsp?HABITAT=NBNSYS0000019604<br>QSR Wadden Sea 2004, Chapter 8;<br>http://www.waddensea-secretariat.org/QSR/index.html<br>http://www.synbiosys.alterra.nl/natura2000/documenten/profielen/habitattypen/profiel_habitattype_1140.pdf (national report on the status of this habitat for the habitat directive, in Dutch) |
| *Norway* | Y | Y | http://data.nbn.org.uk/habitat/map.jsp?HABITAT=NBNSYS0000019604 |
| *Portugal* | Y | | |

| | | | |
|---|---|---|---|
| *Spain* | | | |
| *Sweden* | Y | Y | http://data.nbn.org.uk/habitat/map.jsp?HABITAT=NBNSYS0000019604 |
| *UK* | Y | Y | http://www.ukbap.org.uk/UKPlans.aspx?ID=34<br>Elliott M., Nedwell S., Jones N.V., Read S.J., Cutts N.D. & Hemingway K.L., 1998. Intertidal Sand and Mudflats & Subtidal Mobile Sandbanks (volume II). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs.151 pp.<br>http://www.ukmarinesac.org.uk/pdfs/sandmud.pdf |

## Summaries of country-specific information provided

**European Commission**

**Table 4:** National conclusions drawn for the EU habitat 1140: "Mudflats and sandflats not covered by seawater at low tide" Courtesy of the French Natural History Museum Natural Heritage Service.

| Country | Distribution area | Surface area | Structure and functions | Futur perspectives | Global Evaluation |
|---|---|---|---|---|---|
| Belgium | Favourable (FV) | Favourable (FV) | Unknown (XX) | Favourable (FV) | Favourable (FV) |
| Denmark | Favourable (FV) | Unknown (XX) | Bad (U2) | Unknown (XX) | Bad (U2) |
| France | Inadequate (U1) | Inadequate (U1) | Inadequate (U1) | Inadequate (U1) | Inadequate (U1) |
| Germany | Favourable(FV) | Favourable (FV) | Favourable(FV) | Unknown(XX) | Favourable(FV) |
| UK | Favourable (FV) | Favourable (FV) | Bad and deteriorating (U2-) | Bad and deteriorating (U2-) | Bad and deteriorating (U2-) |
| Ireland | Favourable (FV) | Favourable (FV) | Inadequate (U1) | Inadequate (U1) | Inadequate (U1) |
| Netherlands | Favourable (FV) | Favourable (FV) | Inadequate (U1) | Inadequate (U1) | Inadequate (U1) |

**United Kingdom:** The total UK estuarine resource has been estimated as *c.* 588 000 ha of which 55% is intertidal area, mostly mud and sandflats with a lesser amount of saltmarsh. Intertidal flats cover about 270 000 ha. The UK has approximately 15% of the north-west European estuarine habitat.Mudflats are widespread in the UK with significant examples in the Wash, the Solway Firth, Mersey Estuary, Bridgwater Bay and Strangford Lough.

It has been estimated that sea level rise will result in a loss of 8000 to 10 000 ha of intertidal flats in England between 1993 and 2013. Much of this loss is expected in southern and south-east England although research suggests that the major firths in Scotland will also be affected. The rise results from sinking of the land following the end of the last ice age, plus the effects of global warming. Low water

moves landward, but sea defences prevent a compensating landward migration of high water mark with the result that intertidal flats are squeezed out.

Land claim, for urban and transport infrastructure and for industry, has removed about 25% of Great Britain estuarine intertidal flats and up to 80% in some estuaries. Loss of mudflats reduces estuary productivity and may influence other estuary habitats such as saltmarsh. Although land claim has slowed considerably in recent years, it has not stopped.

The Environment Agency (EA), and local authorities in England and Wales, with guidance from Department for Environment, Food and Rural Affairs (Defra) and Welsh Assembly Government (WAG) develop Shoreline Management Plans (SMPs). The main remit of SMPs is for flood and coast protection and includes recognition of the important role played by mudflats in protecting low lying coastal features. In Scotland, Scottish Natural Heritage (SNH) is leading the Firths Initiative and SMPs are also being developed. The UK Marine SAC project funded by the EU LIFE programme developed management schemes, including mudflats to be implemented under the EC Habitats Directive. Further details may found on http://www.ukmarinesac.org.uk. Many intertidal flats are also covered by Estuary Management Plans (EMPs). Many Local Nature Reserves, designated by local authorities, but often managed by Wildlife Trusts, are in upper intertidal areas and can benefit both saltmarsh and mudflats. Wildlife Trusts and the Royal Society for the Protection of Birds (RSPB) also own and/or manage mudflats within estuarine and coastal reserves.

A significant number of projects creating new saltmarsh and intertidal areas have now been completed. Further details can be found on the Biodiversity Action Plan website (UKBAP: http://www.ukbap.org.uk/UKPlans.aspx?ID=34).

**France:** The main non-vegetated mudflats are situated in estuaries (notably the Seine, Loire and Gironde estuaries) and sheltered bays (Mont-Saint-Michel, Aiguillon, Somme, Veys and the pertuis Charentais). In certain sites (the gulf of Morbihan and Arcachon Bay) they have been abundantly colonised by *Zostera noltii* and are therefore come under a separate OSPAR habitat definition.

At present no coordinated and validated inventory exists for the entirety of intertidal mudflats in France for which data must still be collated, even though spatial data on its overall distribution exists and has been transmitted to OSPAR. A standardised mapping project for this habitat is being carried out for all Natura 2000 areas whose perimeter encompasses the marine zone and should permit rapid progression in this thematic, as all the main mudflats fall under the remits of either the Habitats of the Birds Directives.

**Ireland:** A Conservation Assessment of the EU habitat “Mudflats & Sandflats not covered by seawater at low tide” (Code 1140) is available (http://www.npws.ie/en/media/Media,6232,en.pdf). The area of mudflats and sandflats encompasses 566.72km². The two largest sites are located in the mid-west (Shannon Estuary) and north-east (Dundalk Bay).

**Portugal:** The Tagus estuary is one of the most important Portuguese coastal wetlands and the largest estuarine system. Part of the estuary was established as a Nature Reserve in 1976, and later, in 1994, a larger area was classified as a Special Protection Area, under the EC Birds Directive.

**Denmark, the Netherlands and Germany:** A detailed description of the Wadden Sea intertidal area can be found under chapter 8 of the Wadden Sea Quality Status Report 2004 (Essink *et al*., 2005), which can be consulted at:

http://www.waddensea-secretariat.org/QSR/chapters/QSR-08.1-8.2-tidal-area.pdf

A new Wadden Sea QSR is under preparation and will be ready by November 2009.

On 26 June 2009, the Dutch-German Wadden Sea was inscribed on the World Heritage List by the UNESCO World Heritage Committee at its meeting in Seville (Decision 33 COM 8B.4) http://whc.unesco.org/en/sessions/33com

The decision was taken on the basis of the nomination dossier which was submitted to the World Heritage Center, UNESCO, Paris on 30 January 2008.

The nomination dossier, as submitted to the UNESCO World Heritage Centre, can be consulted at http://www.waddensea-secretariat.org/management/whs/whs.html.

The dossier was evaluated by the advisory body to the World Heritage Committee, the World Conservation Union (IUCN), after registration and assessment of completeness by the World Heritage Center (IUCN Field Mission September 2008).

The TMAP (Trilateral Monitoring and Assessment Programme) covers the entire Wadden Sea area including islands and offshore areas and spans a broad range from physiological processes over population development to changes in landscape and morphology. The TMAP common package was implemented based on a decision at the Ministerial Conference in Stade 1997.

The TMAP has been revised by the Interrreg IIIB HARBASINS project in 2005 – 2008, as a pilot project of an integrated monitoring and assessment concept for a coherent coastal ecosystem shared by three countries (NL, D, DK). It matches the various approaches and instruments for management, monitoring and assessment and combines the requirements of the EC Water Framework, Habitats and Birds Directives and other relevant agreements.

This **TMAP Handbook** provides the framework for future technical adaptations and amendments of the Wadden Sea monitoring and is a tool that combines monitoring in the field with the various levels of assessment and reporting requirements by the EU and other international programmes. It contains:

- An overview of all relevant monitoring requirements and assessment tools,
- A list of monitoring parameters and parameter groups,
- Monitoring methods,
- Monitoring stations,
- A list of responsible authorities,
- A link to TMAP data exchange including spatial data (TMAP Data Manual).

The **TMAP Handbook** is an interactive system based on a relational database which allows different surveys on the monitoring programme in relation to the different monitoring and reporting requirements. This allows different overviews on the monitoring programme either from various EC Directives, OSPAR or other programmes (CMS, Ramsar). The TMAP Monitoring Handbook thus connects the ecosystem view with the (partly) sectoral or non-Wadden Sea views of the other conventions and Directives and lays the foundation of further harmonization of tools and approaches. (http://www.waddensea-secretariat.org/TMAP/Monitoring.html)

For the German North and Baltic Seas a national monitoring which fulfils all the obligations of the Helsinki- and OSPAR Convention is coordinated by a group of all relevant administrational bodies, the so called “Marine Expert Group” (Expertengruppe Meer) established in 2007 to set up an independent marine monitoring for reporting obligations of the WFD, NLK in marine areas and the future obligations of the MSFD.

Also in Germany, an Ad Hoc Working Group on Habitat Types (BMLP AG-WRRL) monitors intertidal mudflats. The monitoring program serves as a basis for reporting under the WFD and the Habitats Directive.

# Annex 2: Description of the proposed monitoring and assessment strategy

Annex III of Elliott's (1998) report (http://www.ukmarinesac.org.uk/pdfs/sandmud.pdf) gives particular and illustrative features of the methods of monitoring this habitat.

For the Wadden Sea there is a well designed monitoring programme which is continually revised. Quality Status reports based on the monitoring appear every 4-5 years (http://www.waddensea-secretariat.org/QSR/index.html ).

## Rationale for the proposed monitoring and use of existing monitoring programmes

In order to compliment and rationalise existing monitoring programmes, the assessment for this habitat should take into account the work currently underway for the Water Framework Directive and for the Natura 2000 sites which can be summarised by two key objectives:

- a regular surface area assessment of this habitat in order to evaluate its destruction, erosion or accretion
- an assessment of the conservation status of the benthic macrofaunal and microphytobenthos communities

A survey of the fish and bird populations linked to this habitat could also be used to evaluate its functional value, with the help of one or several EcoQO's developed on certain aspects.

## Use of existing monitoring programmes

- Water Framework Directive
- Natura 2000 (both the EC Habitats and Birds Directives imperatives)
- Wetlands International International Waterbird Census (IWC)
- The Wadden Sea Monitoring Programme (TMAP)

## Synergies with monitoring of other species or habitats

The imagery that needs to be acquired in order to assess the surface area coverage of this habitat be done in synergy with those habitats which form biogenic structures atop of intertidal mudflats (eg. Intertidal *Mytilus edulis* beds on mixed and sandy sediments; *Ostrea edulis* beds; *Zostera* beds).

The monitoring of waders and flatfish nurseries at a national level should be created or amplified in order to compliment the habitat mapping with qualitative measures of the functional value of this habitat.

## Assessment criteria

It is considered impractical, because of the wide and undefined variability in the systems, at present to derive well-defined and numerical limits as standards for use in monitoring. If poorly-defined limits are given without adequate testing these will be unsuitable for use by 'non-experienced' monitoring staff to determine quality and the magnitude of anthropogenic changes (Elliott, 1998).

## Techniques/approaches

The high cost of benthic sampling may mean that it is more practical to only work up a reduced number of replicates or stations with the remainder being carried out to allow full statistical analysis if some change is evident.The frequency of monitoring will be largely determined by financial and time

constraints. Hiscock (1998) recommends following a six year cycle for statutory sites with a proportion of the sites e.g. those which have a particular scientific or conservation interest monitored more regularly at least every three years. Below is a list of illustrative features of the methods of monitoring characteristics of this habitat. Further details can be found in Annex III of Elliott (1998).

**Monitoring of environmental attributes**

*Substratum*

a. Sampling methods
   - core samples

b. Particle analysis and distribution
   - dry sieving, pipette analysis, Coulter counter analysis, and laser granulometry techniques.
   - porosity (gravimetrically and by sonograph interpretation)

c. Organic content
   - loss on ignition
   - chlorophyll levels (spectrophotometric or fluorimetric techniques)
   - particulate organic Phosporus (wet digestion and spectrophotometric analysis)

d. Redox potential
   - hand-held redox probes

e. Trace metal and other persistent contaminants determination (including particulate polycyclic aromatic hydrocarbons (PAHs) and particulate polychlorobiphenyls (PCBs))
   - gas chromatography with mass-spectrometric detection
   - fluorescence and UV absorption

*Hydrological Regime*

- Lagrangian techniques (drifters or drogues)
- Eulerian techniques (current meters)
- Dye tracer techniques
- Turbidity levels (transmitometers or nephelometers)

**Monitoring of biological attributes**

*Macrofauna*

i. Sediment cores
ii. Remote sampling

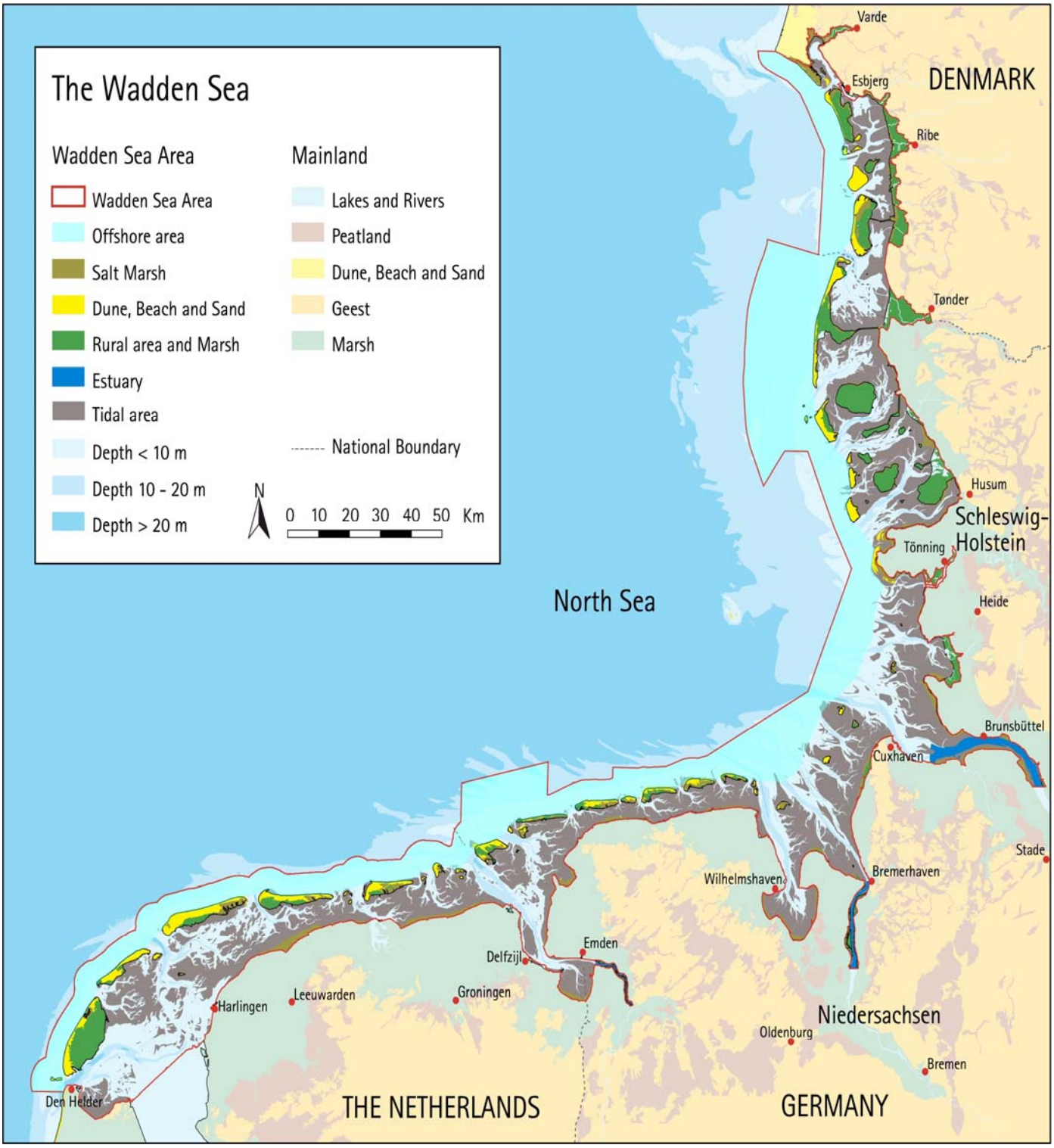
*Birds*

WeBS counts

*Fish*

push nets (juvenile fish); beam trawls

# Annex 3: Map of Habitats in Wadden Sea Area



# Annex 4: References

Atkinson P.W., Crooks S., Grant A. and Rehfisch M.M., 2001. The success of creation and restoration schemes in producing intertidal habitat suitable for waterbirds. English Nature Research Reports 425: 145pp.

Bernem van C. and Lübbe, T., 1997. Öl im Meer. Katastrophen und langfristige Belastungen, Wissenschaftliche Buchgesellschaft, Darmstadt 96 pp.

Bouchet V.M.P and Sauriau P-G., 2008.Influence of oyster culture practices and environmental conditions on the ecological status of intertidal mudflats in the Pertuis Charentais (SW France): A multi-index approach. Marine Pollution Bulletin. In press.

Brown B. and Wilson W.H., 1997. The role of commercial digging of mudflats as an agent for change of infaunal intertidal populations. Journal of Experimental Marine Biology and Ecology 218(1): 49-61.

Common Wadden Sea Secretariat, World Heritage Nomination Project Group, 2008. Nomination of the Dutch-German Wadden Sea as World Heritage Site. Wadden Sea Ecosystem No. 24. Common Wadden Sea Secretariat, Wilhelmshaven, Germany. 203pp.

Chabrerie O., Poudevigne F., Bureau F., Vinceslas-Akpa M., Nebbache S., Aubert M. Bourcier A. and Alard., 2001.Biodiversity and Ecosystem Functions in Wetlands: A Case Study in the Estuary of the Seine River, France.Estuaries 24(6B): 1088-1096.

Dankers *et al* 2007 Ecologische atlas Waddenzee.

Dauvin J-C. (coord.), 2002. Patrimoine biologique et chaînes alimentaires. Fascicule du programme scientifique Seine-Aval. Ifremer ed., (7), Plouzané. 47 pp.

Desroy N., Baron M., Payen C. and Dauvin J-C., 2004. L'estuaire de la Seine: zone de conflit entre développement économique et préservation de l'environnement. Océanis 30(1): 71-93.

Durell S.E.A., Stillman R.A., Triplet P., Aulert C., Biot D., Bouchet A., Duhamel S., Mayot S. and Goss-Custard J.D., 2005. Modelling the efficacy of proposed mitigation areas for shorebirds: a case study on the Seine estuary, France. Biological Conservation 123: 67-77.

Elliot M. and McLusky D.S., 2002. The need for definitions in understanding Estuaries. Estuarine Coastal and Shelf Science 55: 815–827.

Elliott M., Nedwell S., Jones N.V., Read S.J., Cutts N.D. & Hemingway K.L., 1998. Intertidal Sand and Mudflats & Subtidal Mobile Sandbanks (volume II). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs.151 pp.

Essink, K., Dettmann, C., Farke, H., Laursen, K., Lüerßen, G., Marencic, H. and Wiersinga, W. (Eds.), 2005.

Wadden Sea Quality Status Report 2004. Wadden Sea Ecosystem No. 19. Trilateral Monitoring and Assessment Group, Common Wadden Sea Secretariat, Wilhelmshaven, Germany.

Goeldner-Gianella L., 2007.Perceptions and Attitudes Toward De-polderisation in Europe: A Comparison of Five Opinion Surveys in France and the UK. Journal of Coastal Research 23(5): 1218-1230.

Goss-Custard J.D., 1985. Foraging behaviour of wading birds and the carrying capacity of estuaries. In: (eds. Sibley R.M. & Smith R.H.) Behavioural Ecology. Blackwell Scientific Publications, Oxford. pp 169-188.

Hacker S.D., Heimer D., Hellquist E., Reeder T.G., Reeves B., Riordans T.J. and Dethier M.N., 2001.A marine plant (Spartina anglica) invades widely varying habitats:potential mechanisms of invasion and control. Biological Invasions 3: 211-217.

Hiscock K. (1998). Biological monitoring of Marine Special Areas of Conservation: a handbook of methods for detecting change. Part 1. Review and description of methods. Consultation draft. Peterborough, Joint Nature Conservation Committee.

OSPAR 2003. Criteria for the identification of species and habitats in need of protection and their method of application (the Texel-Faial Criteria). OSPAR Commission, London (Reference Number: 2003-13).

OSPAR 2008. Case Reports for the List of Threatened and/or Declining Species and Habitats in the OSPAR Maritime Area. London, OSPAR Commission.

Prater A.J., 1981. Estuary Birds of Britain and Ireland. (eds.) T & A D Poyser Ltd. 440pp.

Ravenscroft N.O.M., Beardall C.H., 2003.The importance of freshwater flows over estuarine mudflats for wintering waders and wildfowl. Biological Conservation 113: 89–97.

Widdows J., Bale A.J., Brinsley M.D., Somerfield P. and Uncles R.J., 2007. An assessment of the potential impact of dredging activity on the Tamar Estuary over the last century: II. Ecological changes and potential drivers. Hydrobiologia 588:97–108.

Wolters M., Garbutt A. and Bakker J.P., 2005. Salt-marsh restoration: evaluating the success of de-embankments in north-west Europe. Biological Conservation 123: 249-268.

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