OSPAR COMMISSION

Protecting and conserving the North-East Atlantic and its resources

Background document on Intertidal *Mytilus edulis* beds on mixed and sandy sediments

Biodiversity and Ecosystems Series

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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. The Contracting Parties are Belgium, Denmark, the European Union, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

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. Les Parties contractantes sont l'Allemagne, la Belgique, le Danemark, l'Espagne, 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, la Suisse et l'Union européenne.

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Cover page: © Gerald Millat

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Draft background document on Intertidal *Mytilus edulis* beds on mixed and sandy sediments

Executive Summary

This background document for Intertidal *Mytilus edulis* beds on mixed and sandy sediments 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 2004. The original evaluation used to justify the inclusion of Intertidal *Mytilus edulis* beds on mixed and sandy sediments in the OSPAR List is followed by an assessment of the most recent information on its status (distribution, extent, and condition) and key threats. Chapter 7 provides recommendations for the actions and measures that could be taken to improve the conservation status of this habitat. In agreeing to the publication of this document, Contracting Parties have indicated the need to further review these proposals. Publication of this background document does not, therefore, imply any formal endorsement of these proposals by the OSPAR Commission. On the basis of the further review of these proposals, OSPAR will continue its work to ensure the protection of Intertidal *Mytilus edulis* beds on mixed and sandy sediments, where necessary in cooperation with other competent authorities. This background document may be updated to reflect further developments or further information on the status of the habitat if such information becomes available.

Récapitulatif

Le présent document de fond sur les bancs intertidaux de *Mytilus edulis* sur des sédiments mixtes et sableux 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 2004. L'évaluation d'origine permettant de justifier l'inclusion des bancs intertidaux de *Mytilus edulis* sur des sédiments mixtes et sableux 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. Le chapitre 7 fournit des propositions d'actions et de mesures qui pourraient être prises afin d'améliorer l'état de conservation de l'habitat. En se mettant d'accord sur la publication de ce document, les Parties contractantes ont indiqué la nécessité de réviser de nouveau ces propositions. La publication de ce document ne signifie pas, par conséquent que la Commission OSPAR entérine ces propositions de manière formelle. A partir de la nouvelle révision de ces propositions, OSPAR poursuivra ses travaux afin de s'assurer de la protection des bancs intertidaux de *Mytilus edulis* sur des sédiments mixtes et sableux le cas échéant avec la coopération d'autres organisations compétentes. Ce document de fond pourra être actualisé pour tenir compte de nouvelles avancées ou de nouvelles informations qui deviendront disponibles sur l'état de l'habitat.

1. Background Information

Name of habitat

Intertidal *Mytilus edulis* beds on mixed and sandy sediments

Definition of habitat

Sediment shores characterised by beds of the mussel *Mytilus edulis* occur principally on mid and lower shore mixed substrata (mainly cobbles and pebbles on muddy sediments) but also on sands and muds. In high densities (at least 30% cover) the mussels bind the substratum and provide a habitat for many infaunal and epibiotic species. This habitat is also found in lower shore tide-swept areas, such as in the tidal narrows of sealochs. A fauna of dense juvenile mussels may be found in sheltered firths, attached to algae on shores of pebbles, gravel, sand, mud and shell debris with a strandline of fucoids. (OSPAR Agreement 2008-7: Descriptions of habitats on the OSPAR List of threatened and/or declining species and habitats)

Correlation with habitat classification scheme

In the EUNIS classification[1] the mussel beds can be subdivided into different habitat types, depending on their sedimentologic surroundings, meaning the mussel beds are either found on littoral mixed substrata (A2.7211) or on littoral sands (A2.7212). In the National Marine Habitat Classification for Britain and Ireland (JNCC Database; Connor *et al*., 2004) *Mytilus edulis* beds have been subdivided into the same two types (*Mytilus edulis* beds on littoral sand – LS.LBR.LMus.Myt.Sa[2] and *Mytilus edulis* beds on littoral mixed substrata – LS.LBR.LMus.Myt.Mx[3]), and are defined as the following:

***Mytilus edulis* beds on littoral mixed substrata (A2.7211/ LS.LBR.LMus.Myt.Mx)**

Biotope description: Mid and lower shore mixed substrata (mainly cobbles and pebbles on fine sediments) in a wide range of exposure conditions and with aggregations of the mussel *Mytilus edulis* colonizing mainly the sediment between cobbles, though they can extend onto the cobbles themselves. The mussel aggregations can be very dense and support various age classes. In high densities the mussels bind the substratum and provide a habitat for many infaunal and epifaunal species. The wrack *Fucus vesiculosus* is often found attached to either the mussels or the cobbles and it can occur at high abundance. The mussels are also usually encrusted with the barnacles *Semibalanus balanoides*, *Elminius modestus* or *Chtamalus* spp., especially in areas of reduced salinity. The winkles *Littorina littorea* and *L. saxatilis* and small individuals of the crab *Carcinus maenas* are common amongst the mussels, whilst areas of sediment may contain the lugworm *Arenicola marina*, the sand mason *Lanice conchilega* and other infaunal species. Pools are often found within the mussel beds that support algae such as *Chondrus crispus*. Where boulders are present they can support the limpet *Patella vulgata*, the dogwhelk *Nucella lapillus* and the anemone *Actinia equina*. *Ostrea edulis* may occur on the lowest part of the shore. There are few infaunal samples for this biotope; hence the characterizing species list below shows only epifauna. Where infaunal samples

[1] http://eunis.eea.europa.eu/habitats/584/species

[2] http://jncc.defra.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00002028

[3] http://jncc.defra.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00002030

have been collected for this biotope, they contain a highly diverse range of species including nematodes, *Anaitides mucosa*, *Hediste diversicolor*, *Polydora* spp., *Pygospio elegans*, *Eteone longa*, oligochaetes such as *Tubificoides* spp., *Semibalanus balanoides*, a range of gammarid amphipods, *Corophium volutator*, *Jaera forsmani*, *Crangon crangon*, *Carcinus maenas*, *Hydrobia ulvae* and *Macoma balthica*.

Situation: On more exposed predominantly rocky shores this biotope can be found below a band of ephemeral green seaweeds (Eph.X). On sheltered, predominantly rocky shores either a *Fucus vesiculosus* dominated biotope or a biotope dominated by the wrack *Ascophyllum nodosum* (Fves.X; Asc.X) can be found above or the barnacle dominated biotope (Sem.LitX). This biotope is also found in lower shore tide swept areas, such as in the tidal narrows of Scottish sealochs.

Temporal variation: Under sheltered conditions, pseudofaeces may build up over time, creating a layer of mud and changing the biotope to Myt.Mu. Where the stability of the mussed bed depends on the mussels being attached to stable cobbles, a build-up of mud from pseudofaeces may prevent this attachment, making the mussel bed unstable and liable to be washed away during storms.

***Mytilus edulis* beds on littoral sand (A2.7212/ LS.LBR.LMus.Myt.Sa)**

Biotope description: This sub-biotope occurs on mid to lower shore sand and muddy sand. Mussels *Mytilus edulis* grow attached to shell debris and live cockles *Cerastoderma edule*, forming patches of mussels on consolidated shell material, and often growing into extensive beds. The mussel valves are usually encrusted with barnacles such as *Elminius modestus* and *Semibalanus balanoides*, and the mussel bed provides a habitat for a range of species including *Littorina littorea.* The sediment infaunal community is usually rich and very similar to that of cockle beds (CerPo), including cockles *Cerastoderma edule*, the Baltic tellin *Macoma balthica*, and a range of burrowing crustaceans and polychaetes typical for CerPo. Further species that may be present are the sand mason *Lanice conchilega*, sand gaper *Mya arenaria*, peppery furrow shell *Scrobicularia plana*, catworms *Nephtys* spp., and the ragworm *Hediste diversicolor*. The eelgrass *Zostera noltii* may occur.

Situation: This biotope often occurs in large sandy estuaries, or on enclosed shores, alongside other sand and muddy sand biotopes, most notably CerPo. It is possible that Lanice beds (Lan) occur lower down on the shore.

Temporal variation: Where this sub-biotope occurs in very sheltered conditions on muddy sand, it could change to Myt.Mu over time as pseudofaeces build up forming a layer of mud. This cannot happen where wave action or tidal streams wash away pseudofaeces and prevent a buildup. In areas where mussel spat ("mussel crumble") settles on the surface shell layer of cockle beds, the mussel cover may be ephemeral, as is the case in the Burry Inlet.

2. Original Evaluation (2004) against the Texel-Faial selection criteria[4]

List of OSPAR Regions and Dinter biogeographic zones where the habitat occurs

All OSPAR Regions (I to V)

Biogeographic zones: Azores shelf, Lusitanean (Cold/Warm), Lusitanean-boreal, Cold-temperate pelagic waters, Boreal-lusitanean, Boreal, Norwegian Coast (Finnmark), Norwegian Coast (Westnorwegian), Norwegian Coast (Skagerrak), South Iceland – Faroe Shelf

List of OSPAR Regions where the habitat is under threat and/or in decline

Intertidal *Mytilus edulis* beds on mixed and sandy sediments are under threat and/or decline in OSPAR Regions II and III.

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

The habitat 'Intertidal *Mytilus edulis* beds on mixed and sandy sediments' was nominated for inclusion on the OSPAR List of threatened and/or declined species and habitats by the Netherlands in 2004, based on the evaluation of its 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 Agreement 2003-13). The nomination for inclusion cited the criteria decline, rarity, sensitivity, ecological significance, with information also provided on threat.

Table 1: Summary assessment of Intertidal *Mytilus edulis* beds on mixed and sandy sediments against the Texel-Faial criteria.

Criterion	Original assessment	Evaluation
Decline	Significant declines in the extent and biomass of Intertidal *Mytilus edulis* beds on mixed and sandy sediments have been reported in the OSPAR Maritime Area and particularly in Region II. In Germany, a series of surveys covering the whole littoral of Niedersachsen revealed a decrease in the extent of beds and, more drastically, in biomass from roughly 5,000 ha in extent to the late 1950s (100 000 t fresh weight), 2 700 ha in 1989/1990, 1 300 ha in 1994 to 170 ha (1 000 t) in 1996. Following some good spatfalls an area of 1 280 ha survived the severe winter of 1996/97 (Herlyn & Michaelis, 1996; Zens *et al*., 1997). Beds in the Ameland region are also reported to have disappeared after intensive fisheries (Dankers, 1993). Details on the mussel populations of Schleswig-Holstein for a period of nine years are also available and a decrease in biomass of approximately 50% was	Qualifies

[4] OSPAR Case Report for Intertidal *Mytilus edulis* beds on mixed and sandy sediments, OSPAR Quality Status Report 2010

	reported between 1989 and 1990 (Ruth, 1994; Dankers *et al*., 1993). In the Netherlands, Higler *et al*. (1998) observed a serious decline in the populations of mussels between 1988 and 1990, mainly caused by fisheries. The extent if mussel beds decreased from the 1970s to the 1990s. In Denmark, intensive fisheries during 1984 to 1987 almost led to a complete disappearance of the mussel population (Kristensen, 1994; Kristensen, 1995).	
Rarity	Intertidal beds are now rare in some parts of their former range in the Wadden Sea due to fisheries in a period with low spat fall, when mature beds were destroyed. In some areas they are returning slowly and in others there has been no recovery at all in the last 12 years. Less than 10% of the original area in the Wadden Sea is now present (De Jong *et al*., 1999).	Qualifies
Sensitivity	*Mytilus edulis* is widely recognised as being tolerant of a wide variety of environmental variables including salinity, oxygen, temperature and desiccation (Seed & Suchanek, 1992). It is capable of responding to wide fluctuations in food quantity and quality, including variations in inorganic particle content of the water, with a range of morphological, behavioural and physiological responses but is not necessarily particularly tolerant of anthropogenic chemicals (Hawkins & Bayne, 1992; Holt *et al*., 1998). Excessive levels of silt and inorganic detritus are thought to be damaging to *Mytilus edulis* once they accumulate too heavily within the reef matrix (Seed & Suchanek, 1992), although the degree to which this might be influenced directly by water quality rather than production of faeces and pseudofacaes is unclear. *Mytilus edulis* is capable of re-surfacing through a shallow covering of sediment and, in general, is considered to have a strong ability to recover from disturbance (Seed & Suchanek, 1992). Dense phytoplankton blooms can, on occasion, be detrimental to *Mytilus edulis*, although serious effects at the population level have only occasionally been reported (Holt *et al*., 1998).	Qualifies
Ecological Significance	Mussel beds are important in sediment dynamics of coastal systems. They collect sediment and are able to keep up with sea level rise. They protrude from the surrounding mudflats and are important as food source for birds. In the Wadden Sea, 25% of the bird numbers used to occur on mussel beds which only occupied 3% of the overall area (Zwarts, 1991). The morphological structures of littoral areas are also enhanced by the mussel beds even where absent, as remnants are visible as elevations of clay banks or shell layers. Very old beds may also stabilise creek patterns because clay and shell layers are relatively erosion resistant. Mussel beds provide shelter for a large number of species and form and often rare area of hard substrata in areas of soft sediment. Asmus (1987) and Dittmann (1990) found respectively, 41 and 96 allied species. For some species such as the sea anemones, hydroids and eelgrass, the bed provides shelter or permanent water in the tidal pools between the ridges. Others, especially deposit feeding worms, profit from the organic matter that is deposited as pseudofacaes (De Jong *et al.,* 1999).	Qualifies

Threat	Although the mussel beds occur in most of the OSPAR area, the majority and *Mytilus edulis* beds under threat occur in the Wadden Sea and British coastal waters. The extensive, heavily exploited mussel fisheries (especially spat collecting for aquaculture) removed close to the entire stock in the Wadden Sea between 1988 and 1990 (Dankers *et al*., 1999), as well as having knock on effects such as an increased mortality for seabirds (*e.g.* eider ducks) (Kaiser *et al*., 1998), and affecting the benthic diversity. Jones *et al*. (2000), Dankers *et al*. (1999), and others consider that this habitat is under pressure from fisheries activities especially when settlement of spatfall is low. Another threat is from alien species. The introduced Pacific Oyster (Crassostrea gigas) has increased significantly in the Wadden Sea since the beginning of the 21st century and one of the preferred settlement structures for the larvae are existing mussel beds. The result has been a conversion of a large parts of mussel beds into oyster beds. In the Lower Saxony part of the Wadden Sea, for example, every intertidal mussel bed holds at least some oysters (Schieffarth *et al*., 2007) Phytoplankton blooms, produced by nutrient enrichment (*e.g.* industrial and residential sewage discharge, agriculture), are another potential threat to mussel beds (De Jong *et al*., 1999) and Jones *et al*. (1999) have suggested that mussel beds could also have intermediate sensitivity to anti-fouling substances and heavy metal contaminants. The decrease of mussel beds has profound effects on predators such as eider ducks and oystercatchers (Kaiser *et al*., 1998).	Qualifies

3. Current status of the habitat

Distribution in OSPAR maritime area

The distribution of *Mytilus edulis* species complex is circumpolar in boreal and temperate waters, in both the southern and the northern hemispheres extending from the Arctic to the Mediterranean in the North-East Atlantic (Soot-Ryen, 1955).

Intertidal *Mytilus edulis* beds on mixed and sandy sediments are specific to the OSPAR area. The majority are found in the Wadden Sea area (the Netherlands, Germany, Denmark) and in UK waters, although they are also present along the coast of Iceland and Ireland (Jones *et al*., 2000). Historical data report some Intertidal *Mytilus edulis* beds on mixed and sandy sediments along the coast of France, but those records have yet to be confirmed.

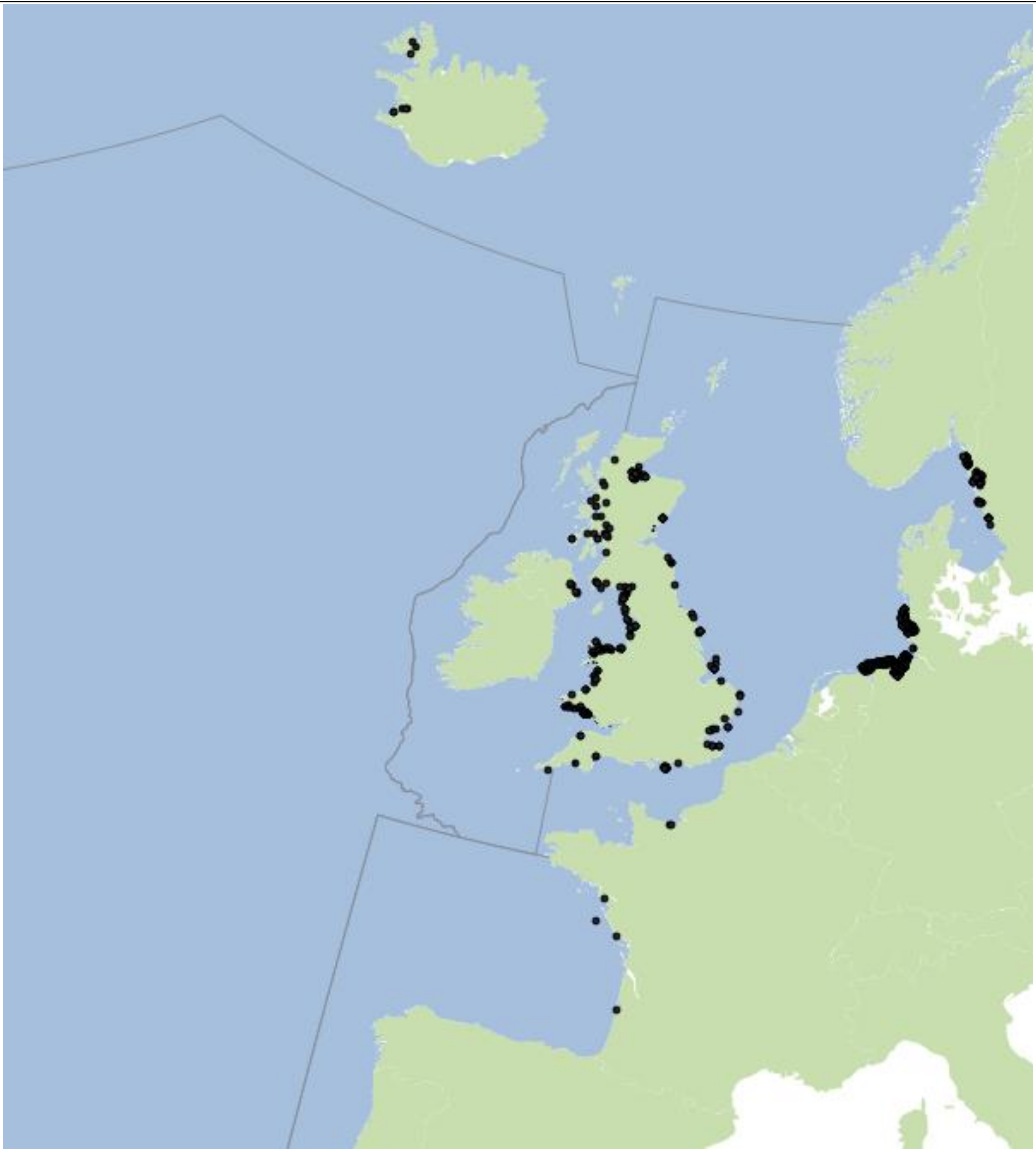

Figure 1: Reported distribution of ‘Intertidal *Mytilus edulis* beds on mixed and sandy sediments’ in the OSPAR maritime area as of 2014[5].

Habitat extent

Many mussel beds are subject to total destruction by storms, ice drifts and tidal surges and on occasion, this may involve hundreds of hectares. For example, the number of mussel beds in the Schleswig-Holstein part of the Wadden Sea mapped by aerial survey decreased from 94 in 1989 to 49 in 1991 as a result of severe storms in early 1990 (Nels & Thiel, 1993). Using data from 1994-2003 it was determined that almost 50% of all newly formed mussel beds in the Dutch Wadden Sea disappeared due to storms and possibly predation in the first winter (Dankers *et al*. 2004; Steenbergen *et al*., 2006).

[5] OSPAR Habitats in the North-East Atlantic Ocean database (2014), http://www.emodnet-seabedhabitats.eu/download, accessed 22/07/2015.

In the United Kingdom, where large beds exist in the Wash, Morecambe Bay, Conwy Bay and other estuaries of south-west England, north Wales and West Scotland as well as the sea loughs of Northern Ireland, the species is considered to be overexploited in places, but not in actual decline (English Nature, 2003).

In the past, numbers and size of mature mussel beds have seriously declined all over the Wadden Sea, although there are regional differences. The lack of spatfall since 1999, fishing for seed mussels in some areas, as well as some winters with heavy storms, have played a role. In the past 10 years, a slow recovery of intertidal mussel beds has occurred in some areas, though in others the decline is ongoing, despite a reduction of seed mussel fishery. The situation of stable subtidal mussel beds is largely unknown.

The policy of the Wadden Sea countries aimed since 1997 for a more sustainable and ecologically sound mussel fishery. In general, major parts of the intertidal now are closed for blue mussel fishery, the area of mussel culture lots has been stable or is reduced and seed mussel fishery is regulated.. In the south-western part of the Wadden Sea, where mussel fishery was particularly intense, these rather large-scale ecosystem changes have been linked to mass mortality of common eiders, as well as oystercatchers (WWF Germany, 2003). While there is some controversy over the exact causes of mortality, evidence suggests that shortages in *Mytilus edulis*, which is the preferred food source for both eiders and oystercatchers, forced those species to feed on lower quality foods (Ens *et al* 2004).

Habitat requirements

Intertidal *Mytilus edulis* beds on mixed and sandy sediments play an important part of a healthy functioning marine ecosystem, having a role in coastal sediment dynamics, acting as a food source for over-wintering waders, and providing an enhanced area of biodiversity in an otherwise sediment-dominated environment.

Table 2: Habitat requirements/environmental preferences for Intertidal *Mytilus edulis* beds on mixed and sandy sediments[6].

Habitat factor	**Range of conditions**
Salinity	Full, variable. *Mytilus edulis* is tolerant of a wide range of salinity compared to other biogenic reef species and may penetrate quite far up estuaries. However, it may stop feeding during short-term exposure to low salinities and the well-developed beds therefore usually occur low on the shore in the mid to lower reaches of estuaries. It is reported greatly- reduced shell growth for a period of up to a month or so upon exposure to 16‰ compared to 26‰ or 32‰, while exposure to 22‰ caused only a small drop in growth rate. In the longer term (in the order of weeks) *M. edulis* adapts well to low salinities and hence can even grow as dwarf individuals in the inner Baltic where salinities can be as low as 4-5‰.
Wave Exposure	Sheltered, Very sheltered, Extremely sheltered

[6] Jones, L.A., Hiscock, K, & Connor, D.W. 2000; http://www.ukmarinesac.org.uk/communities/habitats-review/hr6_1.htm

Substratum	Mixed boulders, cobbles and pebbles on muddy sediment. In sheltered areas infaunal beds may occur on gravel or even quite sandy areas, although it is likely that some harder substratum embedded within the more sandy areas is required for initial settlement. Dense settlement also occurs on cockles in the Wash, Loughor Estuary and Wadden Sea where the byssus of the embedded mussels seems to serve a stabilising function. It has long been suggested that larval *Mytilus* will settle on most substrata provided they are firm and have a rough, discontinuous surface. Settlement is in any case a two-stage process; initial settlement occurs primarily on filamentous substrata such as littoral hydroids and algae, with subsequent secondary dispersal later and development into adult beds.
Zone	Eulittoral-mid, Eulittoral-lower because of requirement of enough submergence time for feeding.
Height	Reef areas are normally found on the lower third of the intertidal, and in shallow subtidal, but can occur down to 10 m in some places such as the Wash, Morecambe Bay and the Wadden Sea. Lower zonational limits for *M. edulis* are usually set by biological factors, normally predation by starfish, crabs and gastropods, and by physical factors. Sand burial has been shown to limit lower regions of *M. edulis* zonation patterns in New Hampshire, USA. This is probably important in some British locations, particularly in the case of cobble and boulder scars in areas of shifting sands such as Morecambe Bay and the Solway Firth. Upper limits of distribution are set by physical factors, but growth and therefore size of animals is also affected by reduced feeding time at higher levels. It has been estimated that growth would be zero at approximately 55% aerial exposure, although clearly this will vary somewhat with local conditions.
Temperature	*Mytilus edulis* is widely distributed throughout the cooler waters of the world. The most limiting factor for distribution world-wide is thought to be temperature. Damage by extreme low temperatures is minimised in *Mytilus* by the use of nucleating agents in the haemolymph. Even in more temperate sites *M. edulis* is periodically subject to potentially lethal freezing conditions, but they can survive even when tissue temperatures fall below -10^{o}C. Tolerance of high temperatures and desiccation can explain the upper limit of *M. edulis* on the high shore. British *M. edulis* have an upper sustained thermal tolerance limit of about 29^{o}C. Recruitment or movement to cracks is known to afford better thermal protection on the upper shore. It can therefore be speculated that dense reef structures might afford some protection from extremes of temperature to the lower animals. In general, however, given the wide temperature tolerance of *Mytilus*, reefs, which are generally found quite low on the shore, are unlikely to be very sensitive to changes in temperature.
Water Quality	*Mytilus edulis* is widely recognised as being tolerant of a wide variety of environmental variables including salinity and oxygen tension as well as temperature and desiccation. It is capable of responding to wide fluctuations in food quantity and quality, including variations in inorganic particle content of the water, with a range of morphological, behavioural and physiological responses. Excessive levels of silt and organic detritus are thought to be damaging to *Mytilus* once they accumulate too heavily within the reef matrix, although the degree to which this might be influenced directly by water quality rather than production of faeces and pseudofacies is unclear.

Condition

The condition of Intertidal *Mytilus edulis* beds on mixed and sandy sediments are profoundly impacted by human activities, most significantly by fishing and harvesting activities. These human disturbances of mature mussel beds on mixed and sandy sediments result in widespread losses and may even lead to long-term disappearances (WWF Germany, 2003). If no further fisheries management measures are taken to avoid natural occurrences of mussel beds to be impacted by harvesting and bottom dredging, the extent of the habitat is expected to shrink further.

Additionally, a scientific study from the European Environment Agency in 2003 has revealed concentrations of PCB, DDT and mercury in blue mussels in the OSPAR region to be higher than background levels in most areas (EEA Topic Report 2/2003), indicating a chemical water pollution in the area.

Limitations in knowledge

There are fragmentary data on the distribution of Intertidal *Mytilus edulis* beds on mixed and sandy sediments in the OSPAR maritime area (please see Figure 1).

It should be noted that individual mussel beds may temporarily disappear. Other may appear nearby or on the same spot, but may be larger or smaller. When mapped on a small spatial scale it is advisable to indicat “mussel bed areas” (Muschelstandorte in German, Mosselgebieden in Dutch) as advocated by Herlyn and Millat (2004), Herlyn *et al*. (2008) and also applied by Dankers *et al*. (2006).

The blue mussel *Mytilus edulis* is used as a sentinel organism for indicating levels of pollutants in coastal marine waters (Calabrese *et al*., 1983). Although a strong emphasis has been placed on marine mussels as biological monitoring organisms (Majori & Petronio, 1973) in recent years, mostly laboratory tests have been performed with exposures of relatively short durations. The lack of long-term observational studies on this species means that little is known about changes that might be the result of exposure to increasing metal concentrations. Intertidal ecosystems have not been studied in detail for enough time to assess the species sensitivity to naturally occurring and human induced environmental changes. The species is also subject to commercial use and aquaculture, and harvested for food throughout the world from both wild and farmed sources.

4. Evaluation of threats and impacts

There is good evidence of the threat to mussel beds from fisheries, especially when this coincides with periods of low spat fall. As an example, the detailed records of the decline of extensive beds in the Wadden Sea provide scientific evidence of the threat to this habitat and its decline along southern North Sea coasts (Dankers *et al*. 2003, Ens *et al*. 2004). In the Netherlands a fishermen hypothesis “limited fishery increases stability of beds by removing soft underlying sediment” was tested. There was no indication that stability was increased. Both fished as unfished experimental plots (almost) disappeared in the following winter (Smaal *et al*., 2004). In that particular winter half of the beds in the region survived to some extent (chapter 6 in Dankers *et al*., 2004)

“To protect intertidal blue mussel beds, considerable parts of the intertidal area of the Wadden Sea have been permanently closed for mussel fisheries since 1997. In The Netherlands intertidal mussel beds have recovered in a few places, but have not reached former levels. Contrary to the Dutch Wadden Sea, mussel beds in Niedersachsen, Schleswig-Holstein and Denmark decreased in the last decade. In these countries the last considerable spatfalls occurred in 1996 and 1997, leading to establishment of beds at a large scale, whereas the establishment of new beds occurred only locally after this. The contrasting developments of natural mussel beds lead to uncertainties regarding the causes of recruitment failure in most areas of the Wadden Sea. Predation on the spatfall seems to be the most important, which again is facilitated by climate change. It is assumed that annual variation in predation rate and recruitment success relates to winter temperatures: cold winters result in low predation rates because the main predators of bivalve spat (*e.g.* shrimp and shore crab) return later in spring to the tidal flats. As a consequence, the bivalve larvae can establish successfully. By contrast, warm winters lead to high predation rates and low recruitment success. In the same time, Pacific oysters spread out very strongly, facilitated by climate change which in turn is leading to more favourable conditions for this species. By now, oysters have densely colonized many former mussel beds in the Wadden Sea, but there is no indication that their spreading has caused the recent decline of the blue mussels in the Wadden Sea. Several studies showed that coexistence might be possible, but the questions whether or not native blue mussel beds will disappear over time due to the rapid spread of the Pacific oyster cannot be answered so far (Diederich, 2005; Betz, 2007). There are several examples of co-existence of blue mussels and oysters in mixed beds (Millat *et al*., 2009, 2012, Millat 2014). In the Dutch Wadden Sea, blue mussels have successfully re-established a strong population in the last years. If sufficient blue mussel recruits manage to settle, new beds may develop and blue mussels may co-exist with oyster beds. (The Wadden Sea Quality Status Report 2009, Thematic Report No. 11, Wadden Sea Ecosystems No. 25)”

Relevant human activity: Fishing, harvesting, bait collecting, land-based activities and coastal developments, mariculture, tourism and recreational activities.

Category of effect of human activity: Physical – anchoring, substratum change, increased siltation, turbidity changes, emergence regime changes, water flow rate, temperature and wave exposure changes. Chemical – contamination by synthetic compounds, heavy metals and hydrocarbons, nutrient changes, water quality changes. Biological – physical damage to the species, removal of target and non-target species.

Decline: There is clear evidence for a decline of mussel beds in areas of intensive fisheries, in the past especially when associated with low recruitment events (Dankers *et al*., 1999; Jones *et al*., 2000). The best reported example is of the extensive, heavily exploited mussel fisheries (especially spat collecting for aquaculture), in the Wadden Sea, which removed close to the entire stock between 1988 and 1990 (Dankers *et al*., 1999). The decrease of mussel beds was also reported to have profound effects on predators such as eider duck and oystercatchers (Kaiser *et al*., 1998, Ens *et al*. 2004).

Non-indigenous species: The settlement of the introduced species Pacific oyster may have a major impact on native mussel beds and their biomass in the OSPAR maritime area, especially in the Wadden Sea. This species has spread out very strongly, facilitated by climate change. Various recent studies have shown that coexistence between *Mytilus edulis* beds and Pacific oyster beds on mixed substrata is possible, but the question whether or not native blue mussel beds will disappear over time due to the rapid spread of the Pacific oyster cannot be answered so far (Diederich, 2005; Betz, 2007; Nehls *et al*., 2009, Millat *et al*. 2009, 2012). It has to be kept in mind that there is no indication that the Pacific oyster spreading has caused the recent decline of *Mytilus edulis* beds in the Wadden Sea. In addition, intertidal mussel beds accommodate an increasing amount of other non-indigenous species which invaded the Wadden sea through mussel imports and other pathways. *Crepidula fornicate* is an invasive species that is found within mussel beds within Swansea Bay. In Carlingford Lough, Belfast Lough and Lough Foyle there are beds that are outside of the aquaculture areas but that are either subject to a 'wild fishery' for mussels or influenced/impacted by the adjacent aquaculture activity. This impact in Belfast Lough has included the introduction of the invasive slipper limpet *Crepidula fornicata* into the 'wild' beds. *Crepidula fornicata* was introduced into Belfast Lough at least seven years ago and is now well established in both subtidal and intertidal habitats.

Table 2: Summary of key threats and impacts to Intertidal *Mytilus edulis* beds on mixed and sandy sediments.

Type of impact	**Cause of threat**	**Comment**	**Scale of threat**
Habitat degradation through smothering & siltation	Aggregate extraction industry; navigational dredging; dredge spoil dumping	Operations leading to significant siltation or smothering of the seabed might be expected to have a significant effect on both intertidal mussel beds and their associated communities, particularly in low energy environments where the silt is unlikely to be dispersed easily. Adequate EIA before such developments begin should identify any risks to the habitat.	Medium
Habitat loss or degradation through physical damage	Fishing/Harvesting/Seed mussel fisheries	Bottom trawling and harvesting of adult and seed mussels is supposed to be the main physical threat to *Mytilus edilus* beds, Trawling damages both mussel beds and associated benthic species and impacts the abiotic environment. Obvious effects include the loss of epifauna and the alteration / degradation of the habitat.	High
Habitat loss or alteration	Infrastructure development	*Mytilus edilus* beds can be damaged by any infrastructure development which disturbs or alters the seabed habitat: oil and gas rigs, trenching and pipe/cable-laying. Provided proper EIAs are undertaken before such developments begin, and sensitive areas of this habitat avoided, the risks can be kept to a minimum.	Low

Change in tidal current regimes	Tidal power schemes; causeway building	*Mytilus edilus* beds tend to occur in areas of low or moderate tidal currents. Any constructions which alter the tidal flow rates in the vicinity of mussel beds could affect their viability, alter the associated communities and potentially lead to loss of the beds.	Low
Changes in sea temperature affecting reproduction	Climate change	*Mytilus edilus* is likely to be impacted by present and future increases in water temperature. The influence of water temperature on the prevalence of diseases is not clear.	Low
Pollution	Land-based and marine industrial or commercial sources	*Mytilus edilus* is known to accumulate contaminants, such as heavy metals, in spoil disposal areas. The effects on condition, reproduction and mortality rates are unknown. *M. edilus* is sensitive to synthetic compound contamination and tributyl tin. Eutrophication may lead to excessive algal blooms, leading to low oxygen levels.	Medium
Diseases/neobiota	Introduction of microbial pathogens/parasites/dispersal of neobiota	There is a wide range of known diseases and parasites of *Mytilus edilus* like trematodes, the polychaete *Polydora ciliata* or the parasitic copepod *Mytilicola intestinalis* which are widely prevalent. Translocation of mussels and mussel seed between *e.g.* mussel culture lots can spread diseases and parasites also into natural mussel beds. This is also valid for the spread of neobiota due to mussel imports/dislocation. Currently also the invasive Pacific oyster (*Crassostrea gigas*) is spreading in the Wadden Sea area, taking over some of the former Mytilus sites.	High
Changes in genetic integrity	Importation and relaying of (seed) mussels of foreign origin on commercial	Mixing of potentially genetically different strains, from a different geographical origin, could result in problems with physiological adaptation; it can affect the genetic diversity of the species, and introduce diseases to non-resistant populations.	Medium

5. Existing management measures

The main management measures, which would assist the conservation of this habitat, are the regulations of fisheries (including spat collection for aquaculture) and protection from physical damage. Intertidal mussel beds have been placed on the red list of biotopes and biotope complexes of the Wadden Sea (Nordheim v *et al*. 1995). In some locations the beds are also a key feature within some of the Annex I habitats listed in the EC Habitats Directive and therefore given protection through the designation of Special Areas of Conservation. They are included under the 'reef habitat' category and EU Member States are to identify representative sites for inclusion in the Natura 2000 network (WWF Germany, 2003).

As an example, in the Wadden Sea, all responsible States have taken steps to protect the wild mussel populations by reducing the impacts of local fisheries on the wider coastal ecosystem (Common Wadden Sea Secretariat, 2002), as regional management plans regulate the harvesting of mussels by license that has led to an establishment of small no-take zones for mussels (WWF Germany, 2003). It has to be kept in mind that the Wadden Sea was already established as a Marine Protected Area (MPA) based on a trilateral agreement setting out common goals and a clear priority on allowing natural processes in the area. The protection of *Mytilus edulis* beds on mixed and sandy sediments in the OSPAR maritime area should be of particular concern, given the mussel beds' role as an important nutrient and natural habitat provider for other organisms.

The policy of the three Wadden Sea countries, including the needs of the Habitat Directive for blue mussel fishery and aquaculture since the Wadden Sea Plan of 1997, aimed for a sustainable and ecologically sound mussel fishery. In general, major parts of the intertidal are closed for blue mussel fishery, the area of mussel culture lots has been stable or is reduced and seed mussel fishery is regulated. In Denmark, the mussel fishery takes place only at natural mussel beds (five licenses) and has for the time being been suspended (2009) due to stock decrease. According to the actual legislation, dispensation may be acquired to fish in three well-defined areas. In Hamburg, mussel fisheries is forbidden by the National Park Act. In Schleswig-Holstein, Niedersachsen and The Netherlands mussel management programmes have been implemented and are being or will be updated. (Wadden Sea Plan 2010, Common Wadden Sea Secretariat, Wadden Sea Ecosystems No. 25, 2009)

The development of fisheries into the direction of more sustainable activities in the Wadden Sea has started and will be continued. Existing national management plans and policies for mussel fisheries are regarded as a step into this direction. The following trilateral policy has been adopted in the Wadden Sea Plan 2010:

- The effects of mussel fishery are limited by the permanent closure of considerable areas and the reservation of sufficient amounts of mussels for birds. In addition, the management of fishery on mussels should not be in conflict with protecting and enhancing the growth of natural mussel beds and Zostera fields;
- Mussel fishery will, in principle, be limited to designated parts of the subtidal area. Based on national management plans, fishery on the tidal flats and parts of the sublittoral may be granted. The fishery sector will, in close cooperation with competent authorities, improve existing

practices in such a way that impacts of mussel fishery in general and seed mussel fishery in particular, will be minimised (WSP 2010).

6. Conclusion on overall status

Mytilus edulis communities have undergone considerable fluctuations in recent decades in the North East Atlantic. Natural sources of mortality include predation, disease, storm damage, wave action, as well as desiccation and siltation. Generally, blue mussels are known to be only moderately sensitive to those natural environmental disturbances, and therefore can recover.

In contrast, pressures such as intensive commercial fisheries and harvesting, coastal development, chemical pollution, and other human activities that physically disturb the mussel bed habitat result in widespread losses and may even lead to long-term disappearances of mature mussel beds on sandy and mixed sediments (Holt *et al*., 1998; Seed & Suchanek, 1992; WWF Germany, 2003; Nehls *et al*., 2009). Recovery from human activity impacts may take at least 5 years, although in certain circumstances and under some environmental conditions (*e.g.* recurring physical disturbance) recovery may take significantly longer (Tyler-Walters, 2008).

7. Action to be taken by OSPAR

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

As set out in Article 4 of Annex V of the Convention, OSPAR has agreed that no programme or measure concerning a question relating to the management of fisheries shall be adopted under this Annex. However, where the Commission considers that action is desirable in relation to such a question, it shall draw that question to the attention of the authority or international body competent for that question. Where action within the competence of the Commission is desirable to complement or support action by those authorities or bodies, the Commission shall endeavour to cooperate with them.

Each Contracting Party could consider:

- the possibility to introduce legislation to protect Intertidal *Mytilus edulis* beds on mixed and sandy sediments;

- investigating the distribution, quality and extent of Intertidal *Mytilus edulis* beds on mixed and sandy sediments, by means of seabed habitat surveys and monitoring, in order to complete the knowledge base and provide indicators for the state and recovery of the habitat;

- whenever applicable, seeking ways and means to broaden the knowledge base on the occurrence of and threats to Intertidal *Mytilus edulis* beds on mixed and sandy sediments by gathering additional knowledge from sources such as national planning authorities, environmental impact assessments and post-development monitoring, research institutes, fisheries research, local sea-fisheries committees, commercial and recreational fisheries, Non-governmental organisations (NGOs) and the general public;

- reporting any existing and new data on the distribution, quality and extent of Intertidal *Mytilus edulis* beds on mixed and sandy sediments to OSPAR;

- assessing whether existing management measures for the protection of Intertidal *Mytilus edulis* beds on mixed and sandy sediments are effective and determine whether further measures are needed to address the key threats;

- whether any sites justify selection and designation as marine protected areas for the conservation and recovery of Intertidal *Mytilus edulis* beds on mixed and sandy sediments and whether such areas may become a component of the OSPAR MPA network;

- addressing and minimising adverse impacts on Intertidal *Mytilus edulis* beds on mixed and sandy sediments arising from human activities such as bottom trawling and harvesting of adult and seed mussels in waters under its national jurisdiction;

- in areas where pressures have caused a decline/disappearance of Intertidal *Mytilus edulis* beds on mixed and sandy sediments, and that are now adequately managed, allowing, where practicable, for a natural recovery of Mytilus to support the recovery of the habitat;

- ensuring by appropriate management that any introduction, hybridisation and intermixture with non-native Mytilus species through marine aquaculture and seed mussel imports/exports and associated invasive and/or non-indigenous species is avoided;

- adapting coastal protection measures in such a way that undesired negative effects on Intertidal *Mytilus edulis* beds on mixed and sandy sediments are avoided or minimised;

- raising awareness for the importance and maintenance of good ecological conditions of Intertidal *Mytilus edulis* beds on mixed and sandy sediments among relevant management authorities, relevant actors, including industry sectors and the general public;

- acting for the fulfillment of the purpose of this recommendation within the framework of other competent organisations and bodies.

Acting collectively within the framework of the OSPAR Commission, with the aim of promoting an ecosystem-based approach, Contracting Parties could:

- improve the OSPAR habitat mapping database in relation to Intertidal *Mytilus edulis* beds on mixed and sandy sediments, and publish regularly updated quality assessments and distribution records;

- communicate the current knowledge base on Intertidal *Mytilus edulis* beds on mixed and sandy sediments to OSPAR Contracting Parties, stakeholders and other competent international authorities;

- intensify efforts, where appropriate, to further reduce discharges and emissions of nutrients and hazardous substances which might affect water quality and thus impacting Intertidal *Mytilus* edulis beds on mixed and sandy sediments.

Brief summary of the proposed monitoring system (see Annex 2)

To improve understanding of the state of Intertidal *Mytilus edulis* beds on mixed and sandy sediments and to follow any changes over time it is important to establish a suitable long-term monitoring of the distribution, quality and extent of this habitat and to assess the effectiveness of any management measures put in place.

In the framework of the Trilateral Wadden Sea Cooperation (TWSC) a Trilateral Monitoring and Assessment Program (TMAP) was developed as common monitoring program for the Wadden Sea carried out by the Netherlands, Germany and Denmark. The 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. It furthermore matches the various approaches and instruments for management, monitoring and assessment, and combines the requirements of the Marine Strategy Framework Directive (MSFD), the Water Framework Directive (WFD), the Habitats and Birds Directives and other relevant agreements. Detailed information on the TMAP Monitoring Handbook can be found in Annex 2.

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 or information provided)**	**National reports, References or web links**
Belgium	N	N	-
Denmark	Y	N	-
France	Y	N	-
Germany	Y	Y – Finalization of draft background document	Millat, G., T. Borchadt, I. Bartsch, W. Adolph, M. Herlyn, K. Reichert, R. Kuhlenkamp, P. Schubert (2012): Die Entwicklung des eulitoralen Miesmuschelbestandes (*Mytilus edulis*) in den deutschen Wattgebieten (aktualisierte Fassung des Berichts 2009/5). - Meeresumwelt Aktuell Nord- und Ostsee, 2012/2, BSH, Hamburg und Rostock
Iceland	Y	N	-
Ireland	Y	N	-
Netherlands	Y	Y – Review of initial draft	-
Norway	N	N	-
Portugal	N	N	-
Spain	N	N	-
Sweden	N	N	-
UK	Y	Y – Review of initial draft	-

Intertidal *Mytilus edulis* beds on mixed and sandy sediments were nominated for inclusion in the OSPAR List in 2004 by the Netherlands.

Annex 2: Description of the proposed monitoring and assessment strategy

TMAP Monitoring Handbook

Tidal Area – Blue mussel beds

(version 15.12.2009, TMAG 09-3, Nehls et al., 2009))

1. Introduction

Beds of the blue mussel (*Mytilus edulis*) are important biogenic structures in the Wadden Sea ecosystem, serving as habitat and as food source for a number of species. In the Wadden Sea Plan (1997, 2010), a specific trilateral Target was formulated aiming for an increase of the total area and a more natural development and distribution of natural intertidal mussel beds, providing a framework for habitat management (Büttger *et al*., 2009).

To protect intertidal mussel beds, in all three countries considerable parts of the intertidal area are permanently closed for blue mussel fishing.

In recent years, Pacific oysters (*Crassostrea gigas*) have overgrown many mussel bed sites and are now often the dominating species (Nehls *et al*., 2005; Dankers *et al*., 2006; Nehls & Büttgers, 2007; Nehls *et al*., 2009). The monitoring of oyster beds can mostly follow the standards defined for blue mussel beds and it is recommended, to conduct combined surveys for both species.

2. Objectives

Trilateral policy and management aims "to achieve, as far as possible, a natural and sustainable ecosystem in which natural processes proceed in an undisturbed way" (Guiding Principle).

With respect to the "Tidal Area" (intertidal and subtidal), the following Target applies (Wadden Sea Plan) to blue mussel beds:

- An increased area of, and a more natural distribution and development of … natural mussel beds.

Monitoring of blue mussels is carried out to document the dynamics of mussel bed development in the Wadden Sea and to detect and assess the response of

- natural processes in the ecosystem to changes in pollution levels;
- species to changes in pollution level which may affect the abundance and physiological functioning of species leading to structural changes in the ecosystem;
- blue mussels to fishing in the Wadden Sea;
- blue mussel beds to global changes (sea level rise).

3. Monitoring requirements

Wadden Sea Plan

Targets on "Tidal Area"

- A natural dynamic situation in the tidal area;
- An increased area of geomorphologically and biologically undisturbed tidal flats and subtidal areas;
- A natural size, distribution and development of natural mussel beds, *Sabellaria* reefs and *Zostera* fields.

Habitats Directive (HD)

Article 11 Monitoring of habitat types

Habitat types 1170 "Reefs", 1110 "Sandbanks", 1140 "Mudflats and sandflats", and 1160 "Large shallow inlets and bays".

Note: designation of blue mussel beds differs in the countries:

- The Netherlands: blue mussel beds are integrated in habitat types 1110 "Sandbanks" and 1140 "Mudflats and sandflats" and not designated as reefs;
- Germany: subtidal blue mussel beds are designated as 1170 "reefs", intertidal blue mussel beds are characteristic features of habitat type 1140 "Mudflats and sandflats";
- Denmark: blue mussel beds are not designated as reefs, blue mussel bed are characteristic features of habitat types are 1110 "Sandbanks" 1140 "Mudflats and sandflats" and 1160 "Large shallow inlets and bays".

Water Framework Directive (WFD)

Annex 5, chapter 1.2.4

Article 4: No deterioration, good status by 2015, reduction of pollutants, achievement of objectives set for protected areas in EC legislation.

Good ecological status of surface water: biological quality element "Macrozoobenthos"

OSPAR

Biological Diversity and Ecosystems Strategy, Annex V and Appendix 3.

Initial OSPAR List of Threatened and/or Declining Species and Habitats (Ref-Nr. 2004-06): "Intertidal *Mytilus edulis* beds on mixed and sandy sediments".

EcoQO Issue 8 "threatened and/or declining habitats": presence and extent of habitats in the North Sea as shown on the Initial OSPAR List: "Intertidal *Mytilus edulis* beds"

4. Definitions

<u>Mussel bed</u>

A mussel bed is a benthic community structured by blue mussels. Similarly, an oyster bed is a benthic community structured by oysters. Both communities mix. Mussel and oyster beds may consist of a spatially well defined irregular collection of more or less protruding smaller beds, which may be called patches, separated by open spaces. This description also includes young beds with a high abundance of small mussels. The described structure may not be so distinct in young beds or just settled beds (spatfall) (TMAP Blue mussel workshop 2002 (CWSS, 2002b)).

Stable bed

Bed where the structure (patches, formed relief) is clearly recognizable over many years (TMAP Blue mussel workshop 2003 (CWSS, 2003); QSR (Dankers *et al*., 1999; Nehls *et al*., 2009)).

Stable site

Location where mature mussel beds (one or more) occur regularly over several years (TMAP Blue mussel workshop 2002 (CWSS, 2002b)).

Assessment criteria for persistence of a mussel bed

Age of bed, type of location, sediment structure of mussel bed basis (TMAP Blue mussel workshop 2002 (CWSS, 2002b)).

Larvae settlement

The first benthic migrating stage of blue mussel larvae smaller than 1 mm is defined as primary settlement. The larvae can settle several times on various substrates until they get larger and settle more permanently on structures such as existing mussel beds or stones (secondary settlement) (TMAP Blue mussel workshop 2000 (CWSS, 2001)).

Spatfall

Settlement of young mussels or oysters on a tidal flat or in existing beds. These small bivalves are called ‘spat’ during the year of settlement only.

Recruitment

The addition of young mussels to the reproducing population. For blue mussels, the concept of recruitment is used for young mussels which survived the winter (age = 1 year).

5. Monitoring strategy

The existing national monitoring programs have been tuned to enable a trilateral assessment for the entire area (*e.g.* by GIS tools) with regard to size and biomass of intertidal mussel. Information on the development of individual mussel beds is also collected to assess status of these beds.

Due to irregular spatfall, larger interannual fluctuations may occur on regional level which requires monitoring with an annual frequency.

Subtidal blue mussel beds are monitored in NL, SH, and DK in the framework of the fishery management and have not yet been integrated in the TMAP.

Table 1: Parameters with monitoring locations and frequencies and the relation to the other monitoring requirements.

Parameters		Location	Frequency	WFD	BHD	OSPAR	Remark
Area and distribution of intertidal blue	size of blue mussel beds	Entire intertidal area	1/y	X	X*	X	

mussel beds:	(km²), coordinates of mussel beds (GIS polygon)						
Biomass	Tons fresh weight	Entire intertidal area	1/y	X	X*		Calculated from selected beds
Coverage	mussel coverage of the beds (%)	Entire intertidal area	1/y	X	X`*		Calculated from selected beds
Additional parameters for individual beds:	length frequency distribution, condition index, structure of bed						Not mandatory

* blue mussel beds as reefs or as characteristic feature of habitat types.

6. Methods

<u>Aerial Surveys of mussel beds in the whole intertidal area</u>

The aim is to get an annual overview about the location and area of all intertidal mussel beds and document it in a trilateral map at a scale of 1:50 000 in order to describe year-to-year changes well as long term developments. Mussel and oyster beds cannot be distinguished from aerial photographs and surveys will in most cases cover both communities.

<u>a. Parameter</u>

The geographical position and the contours of a mussel bed should be determined by aerial photographs (with geo-reference points) in connection with ground truth measurement using GPS to calculate the size of a mussel bed (ha or m² per bed).

<u>b. Frequency</u>

The surveys should be carried out in spring or late August according to national monitoring schemes.

<u>c. Remote sensing methods</u>

Aerial surveys should be carried out to obtain aerial photographs following standard procedures which can be transferred to a GIS (geographical references).

- Aerial photographs (black and white or color)
- Recommended scale: 1:10 000 – 1:25 000. Other scales may be used if appropriate.
- Visual interpretation of images (standard procedures, *e.g.* stereoscopic interpretation).

The sampling strategy should be flexible and adapted to the different types of mussel beds. The number of samples is chosen according to the density of blue mussels at a given location. Preferably, 5 – 10 samples should be taken per bed by corer (7 – 20 cm diameter). A higher number of samples is recommended to detect changes smaller than 50% with a 95% significance.

Location and area

The geographical position and contours of a mussel bed should be determined by GPS following the borders of the bed (as defined under section 2). The size of the bed should be calculated in ha or m².

Coverage

The coverage (“Bedeckung”) gives the percentage of a whole bed covered by mussels. It is an important parameter to characterize a mussel bed. Proportion (“Besatz”) is defined as percentage of the patches occupied by mussels.

Different methods can be used to determine the coverage of a mussel bed. All methods in use obtain results with are more or less comparable. The limitations of each measure should be taken into account, *e.g.* dredge sampling gives more or less an average value whereas surveys on foot obtain more reliable results for individual beds.

A common method used in the Netherlands and Germany is the “Stiefelmethode”: the number of steps on a zigzag shaped transect with and without mussel under the “Stiefel” (boot) is counted and taken as a measure of coverage. Length and position of transects are measured by GPS.

Proportion is measured in patches and gives more detailed information about the mussel distribution within a bed compared to the percentage cover of the total bed especially in beds with a low coverage.

Biomass

Biomass of mussel beds is calculated from fresh weight of mussels (g/m²) and coverage of mussel beds. Fresh weight is determined by weighing or from length-weight relationship to avoid loss of water during the weighing procedure.

Additionally, the ash free dry weight (AFDW) of mussel meat and shell may be measured.

Different procedures and methods can be used under the condition that the results are comparable. Intercalibration exercises for biomass determination should be carried out.

Abundance

The abundance of blue mussels is the number of individuals per unit (sampling area). It is measured by direct counts from corer samples along a transect through the intertidal bed sampled.

Length frequency distribution

The shell length is measured in order to obtain the age structure and to follow the development of spatfall and growth of single cohorts in different years at a given location, and to record recruitment success or failure of blue mussel population in a given area.

Sub-samples may be taken to analyze the length frequency distribution. The shell length is measured according to standard procedures from the umbo to the anterior margin of the shell to the nearest mm.

The statistical program MUSSEL (Bert Brinkman, Alterra) may be applied to analyze the length frequency distribution of mussel beds.

Condition index

The condition index is the ratio between biomass (AFDW or cooked meat) vs. shell length. It should be monitored as a voluntary parameter.

It is measured to obtain an estimate of the nutritional status and viability at a given location and to record the reproductive effort of the blue mussel population in a given area. It gives information about the growth conditions of mussels, the time of spawning, but also if the mussels have a sufficient nourishing-capacity for birds depending on mussel stocks. Standard procedures should be followed to determine AFDW and amount of cooked meet.

Structure and Morphology

The structure and morphology of individual mussel beds should be described mainly as background information and as a voluntary parameter:

- Vertical height profile,
- Thickness and type of accumulated sediment,
- Coverage and biomass of macroalgae,
- Amount of shell grit,
- Amount of barnacles.

Table 2: Overview of parameters measured on **individual** mussel beds (specific sites, not mandatory)

Parameter	Unit	Method
Location and area	ha or m² per bed	GPS, coordinates, contours, aerial photographs
Coverage	% patches per bed	"Stiefelmethode"; estimation
Proportion	% mussels per patch	transect measurements
Biomass	g fresh weight per m² patch	corer/dredge samples; in combination with coverage to calculate biomass per bed and t/ha
Abundance	no./m²	corer/dredge samples
Length frequency distribution	mm	corer/dredge samples
Condition index (voluntary)	-	AFDW or cooked meat vs. shell length
Structure and morphology (voluntary)	-	qualitative description of bed characteristics

7. Parameters

Mandatory parameters:

- Area and distribution of intertidal blue mussel beds: size of intertidal blue mussel beds (km²), coordinates of mussel beds (GIS polygon);
- Biomass: tons fresh weight;
- Coverage: mussel coverage of the beds (%).

Additionally, parameters for individual beds should be monitored (not mandatory) such as:

- Abundance;
- length frequency distribution;
- condition index;
- structure of bed.

8. Frequency and time

Sampling should be carried out on selected beds at least two times per year in spring and autumn. Additional samples may be taken in summer and winter to follow the development over the whole year.

9. Monitoring locations

- Entire intertidal Wadden Sea area;
- Selected intertidal blue mussel bed sites.

10. Assessment

Changes in the abundance of blue mussels *Mytilus edulis* may reflect natural fluctuations (including climate, weather, predation), and/or changes may be caused by fishing, nutrient loads and contaminant levels, or by combinations of these factors. The assessment therefore requires the monitoring information on these impacts. Further, the ecological targets, as agreed at the Trilateral Governmental Conference in Stade (Stade Declaration, 1997), will be used for the assessment in the Wadden Sea:

- A natural dynamic situation in the tidal area;
- An increased area of geomorphologically and biologically undisturbed tidal flats and subtidal areas;
- An increased area and a more natural distribution and development of natural mussel beds, *Sabellaria* reefs and *Zostera* fields.

Table 3: Assessment of intertidal blue mussel beds.

Parameters		**Assessment**	**Objective**
Area and distribution of intertidal blue mussel beds	size of blue mussel beds (km^2), coordinates of mussel beds (GIS polygon)	Trends in area covered over 6 years (total area and sub-areas)	Stable or increasing (taking into account natural fluctuations).
Biomass	Tons fresh weight	Trends in biomass over 6 years (total area and sub-areas)	Stable or increasing (taking into account natural fluctuations).
Coverage	mussel coverage of the beds (%)	Trends in coverage over 6 years (total area and sub-areas)	Stable or increasing (taking into account natural fluctuations).

11. Reporting

The reporting should entail information on used methods and any other information relevant for an assessment of the data. The data can then be delivered to the TMAP data unit, to make it available for trilateral assessment.

The monitoring data of the data originators is mostly stored in GIS covers, databases or spread sheets. The information including the meta data has to be delivered to the national TMAP Data Units where it will be transferred into the trilateral harmonized TMAP database structure.

The monitoring results should be reported annually and made available via the TMAP data unit. Data delivery to the TMAP data unit has to be organized on the national level.

12. Quality Assurance

A successful monitoring program is directly related to the collection and interpretation of relevant and reliable data. In addition to the appropriate collection, preservation, storage and transport of samples, it is vital to establish a system of data quality assurance. This concerns accuracy and precision of sampling and analytical procedures, regular check of the applied methods and intercalibration exercises.

Presently, a common strategy to implement quality assurance procedures in mussel monitoring is not available.

Specific QA activities for blue mussel monitoring should be carried out concerning following issues:

- Intercalibrations campaigns concerning:
    - Sampling strategy and sampling analysis;
    - Detection of the borders of the bed for GPS measurements;
    - Determination of coverage and proportion;
    - Biomass determination.;
- Documentation of sampling methods and applied analysis (*e.g.* determination of productivity, weight- length ratio, water loss) according to a common outline;
- Development of standard operation procedures (SOP);
- Selection of statistical packages to be used.

With regard to the elaboration of quality assurance (QA) procedures, the developments within the JAMP of OSPAR should be followed (OSPAR, 1997).

13. Monitoring Authorities

Denmark

- Danmarks Miljøundersøgelser (DMU/NERI)

Germany

- Landesbetrieb für Küstenschutz, Nationalpark und Meeresschutz (LKN);
- Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN);
- Nationalparkverwaltung Niedersächsisches Wattenmeer (NLPV).

The Netherlands

- Institute for Marine Resources and Ecosystem Studies (IMARES) Yerseke / Texel.

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