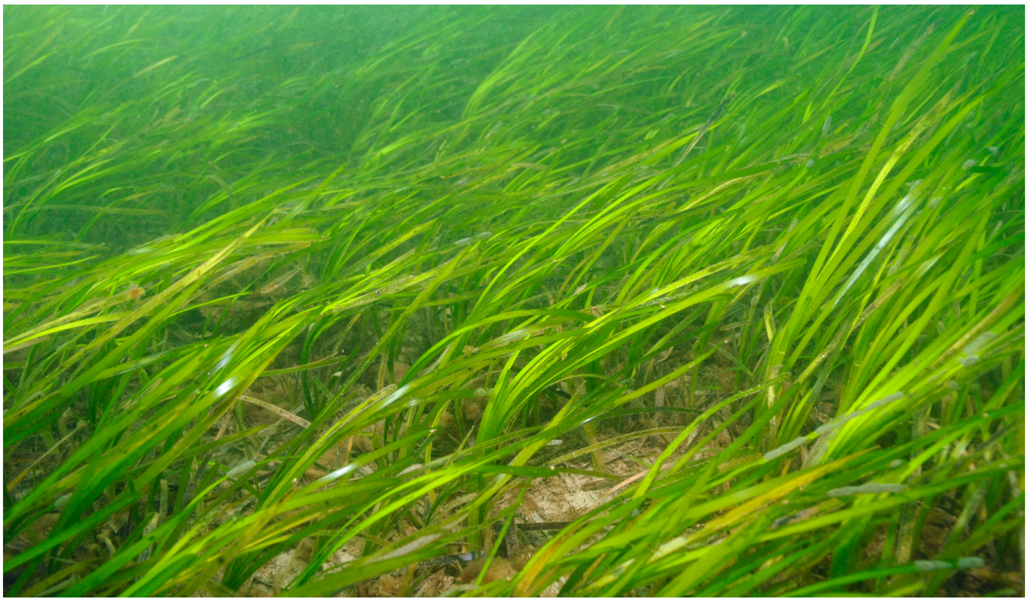
OSPAR COMMISSION

Background Document for *Zostera* beds, Seagrass beds



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

This document has been prepared by Dr. Anita Tullrot, University of Gothenburg, on behalf of Sweden, as lead country for Zostera beds.

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Contents

Background document for *Zostera* beds, Seagrass beds

Executive Summary

This background document on *Zostera* beds 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 *Zostera* beds reefs 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. 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 *Zostera* beds, where necessary in cooperation with other competent organisations. This background document may be updated to reflect further developments or further information on the status of the habitat which becomes available.

Récapitulatif

Le présent document de fond sur les herbiers de *Zostera* 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 herbiers de *Zostera* 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 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 herbiers de *Zostera* 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

Nomination

Zostera beds, Seagrass beds

EUNIS Code: A2.611, A5.533 and A5.545

National Marine Habitat Classification for UK & Ireland code: LS.LMP.LSgr and SS.SMP.SSgr

Definition for habitat mapping

There are two sub-types:

Zostera marina: *Zostera* marina forms dense beds, with trailing leaves up to 1m long (up to 2 m in Western Europe (Brittany France) (Hily et.al. 2003), in sheltered bays and lagoons from the lower shore to about 5 m depth, occasionally down to 10 m (in Sweden and Norway) if water is very clear, typically on sand and sandy mud (occasionally with an admixture of gravel). Where their geographical range overlaps, such as the Solent in the UK, *Z. marina* passes upshore to *Z. noltii*.

Zostera noltii: *Z. noltii* forms dense beds, with leaves up to 20 cm long, typically in the intertidal region (although it can occur in the very shallow subtidal), on mud/sand mixtures of varying consistency.

To qualify as a *Zostera* 'bed', plant densities should provide at least 5% cover (although when *Zostera* densities are this low, expert judgement should be sought to define the bed). More typically, however, *Zostera* plant densities provide greater than 30% cover.

2. Original Evaluation against the Texel-Faial selection criteria

OSPAR Regions and Dinter biogeographic zones where the habitat occurs

OSPAR Regions: I, II, III, IV

Dinter biogeographic zones: Warm-temperate pelagic waters, Lusitanean (Cold/Warm) , Lusitanean-boreal, Cold-temperate pelagic waters, Boreal-lusitanean, Boreal, Norwegian Coast (Finnmark), Norwegian Coast (Westnorwegian) , Norwegian Coast (Skagerrak).

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

Seagrass beds are in decline in OSPAR Regions II & and under threat in all areas where they occur.

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

Two Contracting Parties nominated *Zostera* beds. The criteria common to both nominations were decline, ecological significance and sensitivity, with information also provided on threat.

Decline: There was mass dieback of *Z. marina* throughout Western Europe and elsewhere during the 1920s and mid-1930s due to a wasting disease. More recently, declines have also been reported in the Wadden Sea and the UK for both *Z. marina* and *Z. noltii* (Den Hartog & Polderman, 1975; Jones et al., 2000; Davison and Hughes, 1998). Affected areas are slow to recover.

Ecological significance: Seagrass stabilises the substratum as well as providing shelter and a substrate for many organisms. Where the habitat is well developed the leaves may be colonised by diatoms and algae, as well as stalked jellyfish and anemones. The infauna is generally similar to species occurring in shallow areas in a variety of substrata (e.g. amphipods, polychaete worms, bivalves and echinoderms), and can be rich within the bed. The shelter provided by seagrass beds makes them important nursery areas for flatfish and, in some areas, for cephalopods. The diversity of the species will depend on environmental factors such as exposure and density of the microhabitats, but it is potentially highest in the perennial, fully marine, subtidal communities and may be lowest in intertidal, estuarine, annual beds (Anon, 2000).

Seagrass beds are very productive (an estimated 2g C/m^2/day during the growing season in temperate areas) and often contain a large biomass (up to 5kg/m^2) (Barnes & Hughes, 1982). The living plant is a major source of food for wildfowl, particularly Brent goose and widgeon but also for mute and whooper swans that congregate in areas where *Zostera* is abundant. Only about 5% of seagrass production is thought to be consumed directly and it may be that the dead plant is more important because it is an abundant source of organic matter for marine systems (Barnes & Hughes, 1982).

Sensitivity: The findings from many studies on the sensitivity of *Zostera* beds have been brought together in a review by Davison & Hughes (1998). They include the following information about sensitivity of *Zostera* to different factors.

Sensitivity to turbidity is considered to be high as prolonged increases in turbidity would reduce light penetration and prevent adequate photosynthesis by deeper populations of *Zostera marina*. There may also be a high sensitivity to oxygen depletion but no detailed information is available on this at the present time.

Zostera was considered to have an 'intermediate' sensitivity to other factors such as contamination by synthetic compounds and hydrocarbons, changes in nutrient levels and abrasion (Davison & Hughes, 1998).

Terrestrial herbicides have been found to inhibit growth and cause decline in *Zostera marina* (Delistraty & Hershner 1984). Some effects may be indirect. For instance *Zostera marina* readily takes up heavy metals and TBT (Williams et al. 1994). Whilst plants appeared unaffected, any loss of grazing prosobranchs due to TBT contamination in the leaves or externally would result in excessive algal fouling of leaves, poor productivity and possible smothering.

High nitrate concentrations have been implicated in the decline of *Zostera marina* by Burkholder et al. (1993). Such eutrophication may increase the cover of epiphytic algae and prevent photosynthesis of sea grass. Eutrophication may increase abundance of the slime mold *Labrynthula macrocystis* (the significance of this is that a species of *Labyrinthula* is thought to be the pathogenic agent of wasting disease), however, nutrient enrichment may also stimulate growth of *Zostera marina* (Fonesca et al. 1994).

Apparently healthy *Zostera marina* beds are known to exist in areas subject to low-level chronic hydrocarbon contamination (see, for instance, Howard *et al.,* 1989). Smothering by stranded oil is likely to occur on lower shore populations but little is known of its long-term effects on seagrass beds.

Threat: Physical disturbance, nutrient enrichment, marine pollution, disease, increased turbidity, introduction and competition from alien species are all factors which affect *Zostera* beds and can threaten the extent and quality of this habitat (Anon, 2000). In addition, natural variations in environmental conditions may have a marked effect.

Physical disturbance occurs on both intertidal and subtidal beds. It may be caused by trampling, dredging, use of mobile fishing gear, anchoring, as well as land claim and adjacent coastal development. *Zostera* is generally not physically robust, as the root systems are typically located within the top 20 cm of the sediment and can therefore be dislodged easily (Fonseca 1992). Increased turbidity is another threat and Geisen et al. (1990) suggest that turbidity caused by eutrophication, sand extraction and dredging activities were major factors in the decline of *Zostera* in the Wadden Sea.

Relevant additional considerations

Sufficiency of data: There are many studies on seagrass beds and both general and detailed mapping of their extent and of the associated communities has been carried out in particular locations. Despite this, there are still aspects for which there is a poor understanding. The precise triggers causing the major die-back of *Z. marina* from the wasting disease is one example. In the original case report evaluation this was linked to some combination of the occurrence of the fungus *Labyrinthula macrocystis*, increased turbidity and environmental factors such as water temperature or water quality but this remains unclear (Short et al., 1988). More recent literature suggests *L.zosterae* is the pathogen associated with wasting disease and that other species are reported as non-pathogenic to Zostera (Ralph and Short, 2002).

Changes in relation to natural variability: The extent of seagrass beds may change as a result of natural factors such as severe storms, exposure to air and freshwater pulses. Grazing by wildfowl can have a dramatic seasonal effect with more than 60% reduction in leaf cover reported from some sites. Warm sea temperatures coupled with low levels of sunlight may cause significant stress and die back of seagrass (Anon, 2002).

Expert judgement: There is good evidence of decline and threat to *Zostera* beds in particular locations within the OSPAR Maritime Area with the most detailed studies revealing the decline relating to the North Sea. Factors that threaten *Zostera* beds occur through the OSPAR Maritime Area.

ICES evaluation: ICES concluded in 2002 find that there was good evidence of declines and threat to this habitat. However, they advise that the available literature only covers parts of Regions II and III; hence, a more robust classification might be to confine the classification to these regions rather than Regions II and IV as originally proposed. ICES also note that given the long list of threats, the possibility of combined effects, and the long recovery time of affected beds, it seems reasonable to expect a great vulnerability of *Zostera* beds in the future.

3. Current status of the habitat

Distribution in the OSPAR maritime area

Changes in seagrass beds have occurred at both smaller and larger scales. Most large-scale changes have been documented as changes in area or depth distribution. Overall, the distribution and abundance of seagrass have declined during the last century. The main causes are wasting-disease, reduced water quality and destruction by anthropogenic activities (dredging, anchoring, mooring, harbour development) (OSPAR, 2004). While reductions may be rapid, recolonisation may require long time periods. Once seagrass habitats are lost, restoration (if possible) is therefore likely to require considerable resources. Efficient management must therefore focus upon maintaining existing populations through protection of habitats and monitoring programmes should be designed to detect large-scale changes in time for protective measures to be taken (Krause-Jensen *et al.,* 2004).

Extent of the habitats (current/trends/future prospects)

Changes in *Zostera marina*: The wasting disease in the 1930s caused large-scale decline in *Zostera marina* communities worldwide. Recolonisation after the wasting disease has not led to complete reestablishment of the former distribution and abundance of *Zostera*. In many areas various kinds of anthropogenic disturbances hinder full recolonisation and cause further decline. Reduced water clarity and quality are the main reasons for loss of deep eelgrass populations and are now the most serious causes of global seagrass decline (Krause-Jensen *et al.,* 2004). Examples of long-term changes in *Zostera* beds therefore typically involve decline caused by the wasting disease, incomplete recolonisation and further decline due to eutrophication (Krause-Jensen *et al.,* 2004).

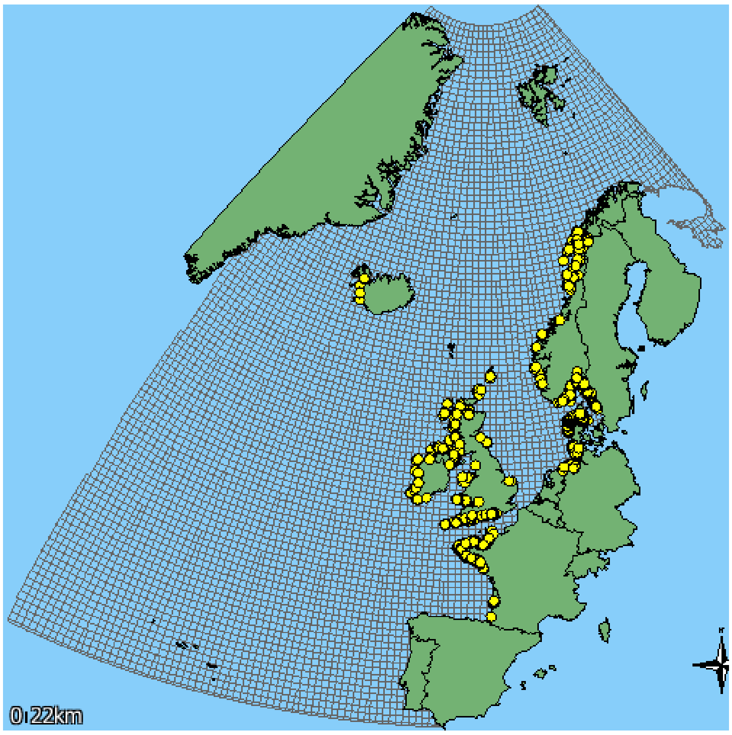

Figure 1. Records (yellow dots) for *Zostera* beds in the OSPAR Maritime Area (Contracting Parties shown in green). Information from Norway, Sweden, Denmark, Germany, France, UK, Ireland and Iceland. (Map from the OSPAR habitat mapping programme hosted by UK, 2009).

Changes in *Zostera noltii*: As in the case of *Z. marina* there are also examples of eutrophication causing changes in *Z. noltii* beds. In the Dutch Wadden Sea, *Z. marina* and *Z. noltii* both declined following the increase of eutrophication in the early 1960s (Borum *et al.,* 2004). In a survey of Western European populations of *Z. noltii* conducted in 1989 and 1990, a few specimens with wasting disease-like damage patterns were found in all investigated populations, but no large-scale deterioration in *Z. noltii* beds was recorded. Small-scale decline in *Z. noltii* was observed in the Dutch Wadden Sea where bioturbation caused by an increased density of lugworms (*Arenicola marina*) smothered young shoots with sediment (Krause-Jensen *et al.,* 2004). Grazing by Brent geese (*Brenta bernicla*) can also significantly affect the distribution of *Z. noltii* beds (Hily *et al.,* 2003).

Future prospects: The widespread loss of seagrass is largely a combination of the direct and indirect impacts of the rapid growth in human activities in the coastal zone. Global population growth is concentrated in the coastal zone, with a high proportion of overall economic value. Indeed, some industries linked to the marine environment, such as tourism, maritime transport and aquaculture are rapidly growing. Consequently, human activity in the coastal zone is likely to continue to increase, with a potential for even greater impacts on seagrass (Borum *et al.,* 2004). Global climate change with predicted increase in global temperature and in frequency and strength of storm events and, in addition, sea level rise may have numerous effects on seagrass distribution in the future (Borum et al 2004).

Rapid recolonisation of damaged beds is possible if the disturbance causing the seagrass decline is limited in time and space and if seedlings originating from the sediment bank or from neighbouring populations experience suitable growth conditions the following year. If the seedlings die and recolonisation must rely on spreading from neighbouring populations, the process can be very slow (Krause-Jensen *et al.,* 2004).

Condition (current/trends/future prospects)

Patchy and sparse *Zostera marina* beds with cover below 60% are generally more vulnerable and suffer greater losses during storms than do dense, uniform beds. This is probably because dense patches possess self-protective properties, which render them more stable. Anoxic events can also induce small-scale changes (Borum *et al.,* 2004).

No information on condition was obtained from Contracting Parties.

Limitations in knowledge

To be able to properly assess the status of *Zostera* beds in the OSPAR area, each Contracting Party must provide the following information:

1. List of regions/locations where *Zostera* beds occur, the condition of these beds and an indication of where it is under threat and/or in decline.
2. A description of recent trends (i.e. recent decades and last ten years) and likely changes in extent over the next ten years.
3. A description of threats and impacts.
4. A description of any management measures to protect the *Zostera* beds and any monitoring programmes.

This information is lacking for most Contracting Parties (see Annex 1). There is some information on records of *Zostera* beds but the condition and threat status are not known. Historical data on distribution are also missing from most countries and may not exist.

4. Evaluation of threats and impacts

Physical, chemical and biological properties of the environment control growth and distribution of seagrasses. Sufficient light, nutrients and inorganic carbon are basic needs, but suitable substratum, moderate exposure, temperature and various biological factors also affect their distribution (Borum et. al., 2004; UK report, 1995).

Human activities have significant impacts on seagrasses. Eutrophication is identified as the major cause of loss of seagrass beds worldwide (Borum *et al.,* 2004). Seagrasses are also vulnerable to t physical disturbance (for example by trampling and from dredging, anchoring and the use of mobile bottom fishing gear), land reclamation, and increased turbidity caused by these and other activities. Other anthropogenic threats are marine pollution and introduction of alien species. The deliberate introduction of the *Spartina anglica* no longer takes place but existing stands continue to spread and compete with native *Zostera*.

The main threats may vary between regions and countries. Ireland has reported that the main threats and impacts on *Zostera* beds are water quality, aquaculture (primarily shellfish farming), fisheries and coastal development (Kelly, pers.com). For the southern English coast, the most important threats are reclamation (construction of quays etc.), mooring, dredging, pollution and siltation (Heape, pers. com). No information from other Contracting Parties is available.

Natural factors such as severe storms, severe frosts, exposure to air and freshwater pulses are also threats. Grazing by wildfowl can have a dramatic seasonal effect with more than 60% reduction in leaf cover reported from some sites. Warm sea temperatures coupled with low level of sunlight may cause significant stress and die-back of seagrass (Anon, 2002). The projected rise in global temperature, increased frequency and strength of storm events and sea level rise associated with climate change all have implications for the distribution of *Zostera* in the future (Borum *et al*. 2004).

5. Existing Management Measures

Berne Convention: *Zostera marina* is strictly protected under the Berne Convention. It does not have a species Biodiversity Action Plan (BAP) but is covered by a Habitat Action Plan (HAP) (Tyler-Walters, 2007).

Natura 2000 network (Marine Habitat type definitions. Update of "Interpretation Manual of European Union Habitats" Annex 1). Eelgrass communities are included in the following habitat types:

1110 Sandbanks which are slightly covered by sea water all the time PAL.CLASS.: 11.125, 11.22, 11.31

1130 Estuaries PAL.CLASS.: 13.2, 11.2

1140 Mudflats and sandflats not covered by seawater at low tide PAL.CLASS.: 14

1150 Coastal lagoons PAL.CLASS.: 21

1160 Large shallow inlets and bays PAL.CLASS.: 12

Conclusion: the provisions of the Habitats Directive protect *Zostera sp.* in designated Natura 2000 sites.

Competent authorities:

Authorities	**Role in the management of *Seagrass* beds**
European Commission	European directives (direct and indirect): Nitrates, Urban Wastewater, Water Framework Directive, Birds and Habitat Directives
European Commission	Designation of Natura 2000 Sites
National Authorities, Provincial Authorities, National Park Administration	Protection, surveillance and monitoring of MPAs for the species (national legislation, Natura 2000 Sites and/or OSPAR MPAs)
Other organisations (e.g. Trilateral Waddensea Secretary)	Protection, communication
OSPAR	Designation of OSPAR MPAs, nutrient reduction programmes

6. Conclusion on overall status

Decline: The decline in *Zostera* beds may have come to a halt in 1990/2000, but it has not re-established its former distribution area prior to the outbreak of wasting disease.

Denmark: After the wasting disease in the 1930s there seems to have been a time lag of more than 10 years before substantial recolonisation began. Substantial recolonisation had taken place in the 1960s. Since then, the area distribution of shallow eelgrass beds has fluctuated markedly without displaying any trend. The deep eelgrass beds of Danish coastal waters have never recovered to their previous extent. While depth limits along open coasts averaged 7-8 m around 1900, they presently average 4-5 m. Depth limits have continued to decrease over this period though a general reduction in nutrient loading and a stabilization in nutrient concentrations in coastal waters. Present distribution area of eelgrass is estimated at 25% of that found in 1900 (Krause-Jensen et al., 2004; Boström et al., 2003).

France: *Zostera marina* has not recovered fully in the Glenan Archipelago following the wasting disease. Eelgrass covered 10 km^2 of the area in 1930 but only 4 km^2. in 2000 (Krause-Jensen *et al.*, 2004). Fishing and anchoring activity most likely contribute to limit the present distribution area.

Arcachon Bay, still has extensive beds of *Zostera noltii*, but as a consequence of eutrophication, massive blooms of green macroalgae have occurred since the late 1980s and constitute a potential threat to the seagrasses. Since 2000 the spatial extent of seagrass beds has decreased. Since 2000 some many undisturbed beds have extended their distribution landwards, resulting in a moderate increase of the total area (OSPAR, 2004).

Iceland: There is no direct indication that the *Zostera* beds are under threat or declining in Iceland (Gunnarsson, pers. com).

Ireland: *Zostera* beds are considered under threat in Irish waters.

Norway: Subtidal *Zostera marina* beds are considered threatened. *Zostera noltii* beds are rare and considered as critically threatened (CR) (Fremstad & Moen, 2001).

Netherlands: In the 1970s and 1980s over 4000 ha of seagrass occurred in the southwest of the Netherlands. At present, very little seagrass is left in these locations and *Z. marina* no longer occurs at all; seagrass beds consist only of *Z. noltii* (Foden, 2007).

Sweden: Between 1980 and 2000, eelgrass cover in five coastal regions on the west coast of Sweden decreased by 58% (Baden et al., 2003). These coastal regions were revisited during 2003 and 2004. Though total cover changed very little between 2000 and 2004, the study showed significant short term variablility, both within a bed and within a region. Some beds that were nearly absent in 2003 were extensive and healthy the following year (MARBIPP, 2006).

Wadden Sea (Netherlands/Germany/Denmark): A decline of intertidal seagrasses in the southern and central Wadden Sea from the 1950s to the 1990s seems to have come to an end, and some slow recovery is evident. Both species, *Z. marina* and *Z. noltii*, show considerable fluctuations between years in the size and shape of local beds. This is also the case in the northern Wadden Sea where no decline was noted (Reise *et al.,* 2005).

Sensitivity: MarLin (*The Marine Life Information Network for Britain and Ireland*) has *Zostera marina* as very highly sensitive to substrate loss, smothering, change in turbidity, change in wave exposure, changes in nutrient levels and introduction of microbial pathogens/parasites (wasting desease). *Z. marina* is also highly sensitive to disturbance (caused by trampling, anchoring, dredging and other activities that disturb the sediment) and introduction of non-native species (eg. *Spartina anglica, Sargassum muticum*) (Tyler-Walters, 2007).

Zostera noltii is highly sensitive to substrate loss, smothering, change in wave exposure, introduction of non-native species and extraction of other species, such as cockles (Tyler-Walters, 2005).

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

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

The most important actions to prevent seagrass loss are (Borum *et al.,* 2004):

- Protection of *Zostera* beds and potential seagrass areas. Studies on the year to year dynamics of the seagrass populations in the Wadden sea and along the Swedish west coast highlight the need to protect potential areas and not only the present seagrass beds (van Katwijk et. al., 2005; MARBIPP, 2006).
- Control and treatment of urban and industrial sewage to reduce the loading with nutrients, organic matter and chemicals.
- Regulation of land use in catchment areas to reduce nutrient runoff and siltation due to soil erosion.
- Regulation of land reclamation, coastal constructions and downscaling of water exchange between open sea and lagoons.
- Regulation of aquaculture, fisheries and clam digging in or adjacent to seagrass beds.
- Raising awareness of the importance of seagrasses (could assist in minimising trampling and anchor damage).
- Implementing codes of conduct to reduce small-scale disturbances.

Management programmes could be designated at both national and international levels and measures could directly or indirectly benefit seagrass beds (Table 1). Protected areas could be designated under the proposed OSPAR MPA programme although seagrass beds are covered by the EU Habitats Directive and could therefore be included in the *Natura 2000* network. OSPAR programmes for nutrient reduction could be intensified.

Table 1. Management programmes under EC directive, international and national supervision that benefits seagrass beds.

Level of management programs		
EC directives	*International supervision*	*National supervision*
Habitats Directive	OSPAR MPA programme	Local
Natura 2000 network	OSPAR programmes for nutrient reduction	National
Water Framework Directive	Trilateral Waddensea programmes	National parks
EU Nitrates Directive		Water management boards
Bird Directive		

Recommendation for further measures and activities:

National and international legislation

- Enforcement of the legislation of protection,
- Recognition of protected areas as priority habitats,
- Include *Zostera marina* and *Z. noltii* in the list of priority species in the *Natura 2000* list of species,
- Protection of areas important potential seagrass habitat to promote recovery,
- Improve and speed up nutrient reduction (nitrogen compounds).

Communication

- Improve the links between local, national and international works,
- Ensure realistic timescales for targets,
- Long-term monitoring including surrounding abiotic factors.

Research, gaps in knowledge

- More research in order to determine appropriate levels of cover for maintenance of the habitat (e.g. Krause-Jensen *et al.,* 2004) in order to improve and underlying ecological information,
- National and regional exchange of data.

Role of OSPAR

- Co-ordinate strategies at the national level for data collation, monitoring and management. This could build on work undertaken under existing mechanisms such as national biodiversity plans (e.g. in U.K.) and *Natura* 2000.
- Link ongoing work together with the Habitat directive (Natura 2000), Water framework directive and the Marine directive to avoid duplication of work.
- Encourage the designation of protected areas both under the OSPAR MPA programme as well as within *Natura* 2000.

- Intensify effort for nutrient reduction.

Brief Summary of the proposed monitoring system

The proposed monitoring system includes high-level monitoring of seagrass distribution using remote sensing data and fine-scale diver assessments of depth limits, degree of cover, biomass or shoot density along depth gradients and health. These indicators all respond to changes in water quality. The upper and lower depth limits of seagrass beds deliver robust indications of overall status. The lower depth limit of seagrasses and their abundance in deep water are the indicators most directly coupled to water clarity as they are primarily light regulated. These indicators should therefore have high priority in monitoring programmes aimed at assessing effects of changes in levels of eutrophication and siltation. Cover and density estimates are highly seasonal and should be monitored during peak vegetation period.

Seagrass monitoring programmes can benefit from including variables on habitat quality in addition to seagrass indicators e.g. occurrence of epiphytes and macroalgal blooms and information on key fauna species associated with seagrass beds. Epiphytes and macroalgal blooms may indicate high nutrient concentrations. Collection of these data will help identify reasons for any observed changes in seagrass cover or health and may also help to identify appropriate management actions. Relevant key fauna to measure in connection with seagrass monitoring programmes may differ between regions.

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	N	Distribution - pers. com	Kerckhof pers.com 2007
Denmark	Y	Distribution-literature Status & trend-literature	Boström et. al. 2003; Krause-Jensen *et al.,* 2004
European Commission		Status to intertidal seagrass assessments, work under WFD	WFD technical report, 2008 Draft Milestone 6 report – Baltic sea GIG, 2007
France	Y	Status & trend-literature	Krause-Jensen *et al.,* 2004 Hily pers. com 2007
Germany	Y	Distribution - pers. com Status & trend-literature	Wadden Sea QSR 2004 Foden, 2007
Iceland	Y	Distribution- pers. com, literature	Gunnarsson pers.com. 2007; Boström et. al. 2003
Ireland	Y	Distribution - pers. com Status & trend-literature	Kelly, pers.com 2007 Foden J. 2007
Netherlands	Y	Distribution - pers. com Status & trend-literature	Wadden Sea QSR 2004 Foden, 2007
Norway	Y	Distribution-literature Status & trend-literature	Boström et. al. 2003 Fremstad & Moen, 2001; DN-håndbok
Portugal			Status & trend-literature: Borum *et al.,* 2004
Spain			
Sweden	Y	Distribution-literature Status & trend-literature	Boström et. al. 2003 Baden *et al.*. 2003; MARBIPP, 2006
UK	Y	Distribution-literature Status & trend-literature	Tyler-Walters, 2005 and 2007 UK Report, 1995; Foden J. 2007

N= No, Y= Yes

Zostera beds were nominated in 2001 for inclusion in the OSPAR List by the Netherlands and the UK. Contact persons:

- **UK:** David Connor, Joint Nature Conservation Committee, Monkstone House, Peterborough PE1 1UA, UK.
- **Netherlands:** Victor N.de Jone, Blauforlaet 22, 9284 XH Augustinusga, The Netherlands.

Summaries of country-specific information provided

National overview of the distribution and extent of *Zostera marina*

Belgium: There are no *Zostera* beds in Belgium (Kerckhof pers.com 2007).

Denmark: *Zostera marina* is the most widely distributed seagrass in Danish waters. It dominates sandy and muddy sediments in coastal areas of low to moderate wave exposure. Very exposed North Sea coasts are devoid of eelgrass (Boström et. al. 2003). Eelgrass grows in the inner parts of brackish estuaries and sheltered bays and in fully marine waters. In areas of low salinity, *Zostera noltii* (and *Ruppia* spp.) can occur at the inner edges of eelgrass (Boström *et al.*, 2003).

France: In France more than 200 sites (including both *Z.marina* and *Z.noltii*) are identified some around 100 m² others many ha (Hily *et al.,* 2003). From the West coast of Normandy to South Brittany numerous *Z. marina* beds (from 100 m² to 10 ha each) occur in sheltered bays (Bay of Brest, Gulf of Morbihan, Bay of Morlaix), around islands (Iroise Sea, Glenan Archipelago) and at the mouths of estuaries and rias (Aber Benoit, Aber-Wrac'h), while *Z. noltii* cover is patchy in very sheltered and often estuarine situations. South of the Loire estuary *Z. noltii* is the dominant marine angiosperm in terms of surface cover on mud flats of the Marennes-Oleron region and in the Arcachon Basin, while *Z. marina* beds form narrow ribbons along the little channels of the muddy banks (Hily *et al.,* 2003).

Germany: Zostera beds occur in the German Wadden Sea area, but specific spatial data are not available (Boedeker pers. com. 2007). Further information will be given in the Wadden Sea QSR 2010.

Iceland: *Zostera marina*. is the only eelgrass species in Iceland. It is known from fifty sites (see attached map) (Gunnarsson, pers.com).

Ireland: Intertidally, *Zostera* communities have been recorded on all Irish coasts. Subtidally, *Zostera* communities have only been recorded from the south, west and north coasts. The habitat is under threat in Ireland (Kelly, pers.com 2007).

Subtidal Zostera records in Ireland

Kinsale Harbour
Roaringwater Bay
Kenmare Bay
Valentia Harbour
Ventry Harbour
Tralee Bay
Galway Bay
Kilkieran Bay
Greatman's Bay
Inis Mor
Mannin Bay
Kingstown Bay
Clew Bay
Blacksod Bay
Broadhaven Bay
Rutland Sound
Mulroy Bay
Lough Swilly
Donegal Bay

Intertidal Zostera records in Ireland

Drumcliffe Bay
Sligo Harbour
Ballysadare
Killala Bay/Moy Estuary
Blacksod Bay
Tralee Bay
Castlemaine Harbour
Dungarvan Harbour
Tramore Bay
Dublin Bay
Baldoyle
Broadmeadow

Netherlands: There is adequate information about seagrass in the Dutch Wadden Sea, however, information about seagrass in the Dutch Delta is missing. In the 1970s and 1980s over 4000 ha of seagrass (both species) occurred in the southwest of the Netherlands, in the Grevelingen, the Oosterschelde and in the Veerse Meer (a small population). At present, very little seagrass is left at these locations. In the past 20 years the cover of *Z.noltii* has decreased by 90% and the cover of *Z.marina* by 98%. The main reason of the decline is the disappearance of freshwater inflow because of the delta-works, causing the water to become too saline. In the Veerse Meer a strong algal bloom, reducing the transparency of the water, recently caused a severe decline.

Norway: *Z.marina* is found along the entire Norwegian coast and extends into the White Sea. It forms isolated populations on shallow exposed and sheltered sandy bottoms (Boström *et al.*, 2003).

Sweden: *Z.marina* is the most widely distributed seagrass on the Swedish west coast. It dominates sandy and muddy sediments in coastal areas of low to moderate wave exposure (Boström *et al.*, 2003). Eelgrass grows in the inner parts of brackish estuaries and sheltered bays and in fully marine waters. In areas of low salinity, *Zostera noltii* (and *Ruppia* spp.) can occur at the inner edges of eelgrass (Boström et. al. 2003).

The Wadden Sea: In 2002/2003, intertidal seagrass beds were distributed rather unevenly. More than 80% of the beds occur in the northern Wadden Sea between Eiderstedt and Skallingen (Wadden Sea QSR 2004).

UK: *Z.marina* has a wide but patchy distribution in southwest England, the Solent and Isle of Wight on the south coast, Wales, western Ireland, western and eastern Scotland including Orkney and the Shetland Islands (Tyler-Walters, 2007). *Zostera noltii* is found in estuaries and bays around Britain with extensive populations in the Moray and Cromarty Firths, the Wash, Essex estuaries, Thames, Argyll coast and Firth of Clyde. It is also reported from Strangford Lough in Northern Ireland (Tyler-Walters, 2005).

National information on the status and trends in condition of Zostera beds

Denmark: The variability in extent and depth distribution of Danish *Zostera* beds has been analysed over a 100-year period from around 1900 to 2000 (Boström *et al.*, 2003). This analysis showed marked variation due to the eelgrass wasting disease in the 1930s and as a consequence of eutrophication. In the Kattegat and Belt Sea, eelgrass was markedly affected by the wasting disease, except in the most brackish areas where the disease did not occur (Krause-Jensen *et al.,* 2004). Aerial photography of shallow Danish *Zostera* distribution shows that beds affected by the wasting disease exhibited a time lag of more than 10 years before substantial recolonisation began, probably reflecting long distances to seed-producing populations and extreme climatic events like storms and icy winters during that period. After the initial time lag, *Zostera* beds recovered rapidly, and substantial recolonisation had taken place by the 1960s. Since then, the spatial distribution of shallow *Zostera* beds has fluctuated markedly without displaying any trend. The deeper water beds have never recovered to their previous extent. While depth limits along open coasts averaged 7-8 m around 1900, they presently average 4-5 m. Despite the general reduction in nutrient loading and a stabilisation in nutrient concentrations in Danish coastal waters over the last decade, the depth limits have continued to decrease. This may be due to bottom-water anoxia, the alteration in sediment conditions and the fact that recolonisation can be a lengthy process (Krause-Jensen *et al.,* 2004).

As a consequence of the loss of the deep beds and reduced cover of shallow beds, the present distribution area of *Zostera* is estimated at 25% of that found in 1900 (Krause-Jensen *et al.,* 2004; Boström *et al.*, 2003). However, considering resilience and long-term persistence Greve and Krause-Jensen (14) concluded that the Danish *Zostera* populations have been quite stable and show potential for recolonizing former areas following the wasting disease.

France: At the Glenan Archipelago (9 miles off the coast of Brittany), where direct effects of eutrophication are small, aerial photography documents that recolonisation after the wasting disease has not generated the former distribution area of *Zostera marina*. In 1930 eelgrass covered 10 km^2 of the area but in 2000 only 4 km^2. Fishing and anchoring activity most likely contribute to limit the present distribution area (Krause-Jensen *et al.,* 2004). Arcachon Bay still has extensive beds of the seagrass *Zostera noltii*, but as a consequence of eutrophication, massive blooms of green macroalgae have occurred since the late 1980s and constitute a potential threat to the seagrasses. Since 2000 the surface decreased. Since 2000 many non perturbated beds are expanding their high limits to the shore resulting in a moderate increase of the total surfaces even if in other sites, human activities reduce the surface (Hily *et al.,* 2003).

Germany: According to the actual German Red List of Biotopes, *Zostera* beds are heavily endangered in the German North Sea, both in habitat quality and in spatial distribution (Boedeker pers. com. 2007; Riecken *et al.,* 2006). Further information is given in the Wadden Sea QSR (due to be updated in 2010).

Iceland: The only species of *Zostera* in Iceland is *Zostera marina*, there is no monitoring of *Zostera*-beds in Iceland at the moment (Gunnarsson, per.com. 2007).

Ireland: As the baselines are just finished or being completed, it is not possible to give an accurate position in relation to recent trends as there do not appear to be any reference values. Likely changes will depend on the effectiveness of management measures and monitoring programmes (Kelly, per.com). Historical data are scarce, but a marked decline in seagrasses since 1930s probably coupled with a change from the earlier dominated *Z marina* to *Z noltii* and *Z. angustifolia* (Foden J. 2007). *Z. angustifolia* is considered by some authors to be an intertidal subspecies of *Z. marina* (Hily *et al.,* 2003).

Netherlands: As recently as 1920 *Z. marina* was recorded in the transition zone between the Zuiderzee and the Wadden Sea, but disappeared following the damming of the Zuidersee. Both *Z. marina* and *Z. noltii* declined following the increase of eutrophication in the early 1960s (Borum *et al*., 2004). This trend was later reversed and the total area of *Z. noltii* almost doubled between the early 1970s and the late 1980s. The total seagrass-covered area was estimated at 150 km^2 in 1919 but at only 5 km^2 in 1971 and 2 km^2 in 1994, when it mainly consisted of *Z. noltii* (Krause-Jensen *et al.,* 2004). *Z. marina* no longer occurs anywhere in the Netherlands (Foden, 2007).

Norway: Subtidal *Zostera marina* beds are considered threatened, *Zostera noltii* beds are rare and considered as critically threatened (Fremstad & Moen, 2001). *Z. noltii* occurs in three areas: Oslofjorden, Jæren and Sunnhordaland. Investigations on *Zostera* beds and of associated flora and fauna has recently been performed at several sites in Oslofjorden and Sørlandet (Tønsberg, Langesund, Risør, Tvedestrand, Arendal) and on the Møre coast *(*DN-håndbok, 2007).

Portugal: There has been a drastic reduction of the *Zostera noltii* bedsin the Mondego estuary. This is attributed to eutrophication in the 1980s, and the occurrence of seasonal blooms of green macroalgae, especially in the southern, most nutrient-rich part of the estuary (Borum *et al.,* 2004).

Sweden: Monitoring of Zostera beds is not yet included in the Swedish National Monitoring Programme for Sea and Coastal Areas. Regional authorities, however, have conducted some surveys along the west coast. In the 1980s, *Zostera* was introduced along the Swedish west coast as a coastal zone management tool to stabilise shorelines. In 2000, five of these locations were revisited. Spatial cover had decreased by 58% (Baden *et al.,* 2003). Subsequent monitoring during 2003 and 2004 showed that the total cover changed very little between 2000 and 2004 (a total increase of 3%). This study also showed large interannual variations, both within a bed and within a region. Some beds that were nearly absent in 2003 were extensive and healthy in 2004. These results indicate that interannual variations are larger than previously known (Marbipp, 2006).

UK: The wasting disease was responsible for die-back of large areas of seagrass in the UK in the 1930s. *Labyrinthula*, the slime mold associated with the disease, has recently reappeared in seagrass beds around the Isles of Scilly (UK Report, 1995). Historic datasets are rare in the UK as there has not been a national seagrass monitoring programme. For many sites, monitoring has been on a local scale and has likely employed one of a variety of methods, limiting the possibility of historical comparisons (Foden, 2007).

Wadden Sea (Neatherlands/Germany/Denmark): Seagrass monitoring in the Wadden Sea is varied in the different subregions, partly due to the widely differing sizes of vegetated areas. As a consequence, the cover of *Z. marina* and *Z. noltii* is still not known for the entire Wadden Sea and general trends in development cannot easily be separated from more local phenomena and fluctuations. A decline of intertidal seagrasses in the southern and central Wadden Sea from the 1950s to the 1990s seems to have come to an end, and some slow recovery is evident. Both *Z.marina* and *Z.noltii*, show considerable fluctuations between years in the size and shape of local beds. This is also the case in the northern Wadden Sea where no decline was noted (Reise *et al.,* 2005). Data from 2002/2003, indicate that a total area of approximately 73 km^2 of seagrass beds are distributed rather unevenly across the region. Approximately 82% of the beds occur in the northern Wadden Sea between Eiderstedt and Skallingen where no long-term decline of seagrasses was noted. The total area covered has increased in the Netherlands and in Niedersachsen. Both *Z. marina* and *Z. noltii* show considerable interannual fluctuations in size and shape of local beds. Salinity and nutrient loading, separately and in combination, are important environmental factors for seagrass development. Local freshwater runoff is considered advantageous for seagrass growth, but the quantity has decreased due to sea dyke strengthening. Eutrophication and hydrodynamics seem to be the major factors determining the distribution of seagrasses in the Wadden Sea, while shellfish fisheries and land reclamation have negative effects on a more local scale. Reintroduction programmes, as in the western Dutch Wadden Sea, may support natural recovery provided that the optimal locations are chosen (Essink *et al.,* 2005).

National information on the existing management measures in OSPAR Contracting Party

France: In France, *Z.marina* beds are considered as determinant ecological components in the Habitats Directive Natura 2000 under the EC 1110 habitat: "Sands and muddy sands, with and without *Zostera marina* beds". *Zostera* beds receive special attention in the operational plans of Natura 2000 sites (Hily *et al.,* 2003). In the Brittany region, the REBENT programme (www.rebent.org) includes monitoring of seven *Zostera marina* beds. Plant, sediment and fauna have been surveyed annually since 2003 (Hily *et al.,* 2003).

Germany: Zostera beds are included in the Trilateral Monitoring Programme of the Common Wadden Sea Agreement (TMAP) between Denmark, the Netherlands and Germany. Results of the last revision, data and guidelines can be found under: http://cwss.www.de/workshops/TMAP-revision/seagrass/seagrass-workshop-2006.html.

Ireland: Some zoning has been pursued in relation to the licensing of aquaculture in SPAs. Baseline mapping is currently underway for subtidal sites while all intertidal sites have been baseline mapped with regular monitoring at key sites under the Water Framework Directive. Site management in Ireland is largely an administrative process through relevant licensing processes (Kelly, pers.com. 2007).

Norway (Nasjonalt program 2007): During the period 2007-2010 there is due to be a survey of the extent and condition of habitats in the coastal zone of Norway, with selected habitats in at least half of the coastal municipality being mapped. It should be possible to follow the development of area extent and condition for the selected habitats. The knowledge obtained will be used in decision-making for area use and resource management.

UK: (Tyler-Walters, 2007). Areas of seagrass occur in numerous coastal MPAs in the UK. Two out of the three UK Marine Nature Reserves have seagrass beds and the habitat occurs in a number of existing and proposed SACs under the EC Habitats Directive. Monitoring of seagrasses occurs in some designated sites but the UK Biodiversity Action Plan report for 2005 indicates that comprehensive data are lacking for the UK in general.

Annex 2: Description of the proposed monitoring and assessment strategy

Rationale for the proposed monitoring

The most widely used parameters in seagrass monitoring programmes aiming to observe and detect changes in abundance are cover and density of seagrass meadows. The methods used are either direct observations of the distribution of the meadows, often along transects, or by remote sensing (satellite or airborne remote photography, or side scan sonar) (Borum *et.al.*, 2004).

The proposed monitoring system includes monitoring of seagrass distribution and abundance from coarse assessments of presence/absence or area distribution of seagrasses in large areas (with remote sensed data) to fine-scale diver assessments of depth limits and of cover, biomass or shoot density along depth gradients. These indicators all respond to changes in water quality. The upper and lower depth limits of the meadows deliver robust indications of overall status, as these are easily detectable and occur where stresses are most likely. The lower depth limit of seagrasses and their abundance in deep water are the indicators most directly coupled to water clarity as they are primarily light regulated. These indicators should therefore have high priority in monitoring programs aimed at assessing effects of changes in levels of eutrophication and siltation. Seagrass abundance and area distribution in shallow water are more subjected to physical disturbance like wind- and wave exposure and sediment redistribution and by human impact. The area distribution of entire seagrass beds therefore responds less predictably to changes in water quality than do deep populations, but distribution maps have the advantage of providing large-scale overviews of distribution and extent of beds and are useful and easily eligible supplements to the more detailed monitoring (Borum *et.al.,* 2004). Cover and density estimates are highly seasonal and should be monitored during peak vegetation period.

The selection between different monitoring options is dependent on the structure and resources available. Seagrass monitoring programmes can benefit from including variables on habitat quality in addition to seagrass indicators. Such variables affect the seagrasses, and information on their level may therefore help identify reasons for status and changes in seagrass indicators and suggest corrective measures. Suggested quality indicators are occurrence of epiphytes and macroalgal blooms and information on key fauna species associated with seagrass meadows. Epiphytes and macroalgal blooms indicate high nutrient concentrations. Relevant key fauna to measure in connection with seagrass monitoring programmes may differ between regions.

Many programmes, especially in USA, combine seagrass monitoring with the monitoring of water, and sometimes, sediment quality, such information can help ascertain the causes of trends detected on seagrass meadows, thereby facilitating action. Among the environmental properties monitored, water transparency, measured with the Secchi disc, provides the most robust and simple indication of water quality (Borum et.al., 2004).

Use of existing monitoring programmes

The European Environment Agency (EEA) works at the moment with two types of actions: *Increasing efficiency of monitoring* by simplifying, streamlining and making comparable existing marine monitoring data and *Convergence of assessments* by leading work towards the development of a common set of pan-European marine indicators to be complemented regionally, in order to support the implementation of the European Marine Strategy (EMS) and proposed Marine Strategy Directive’s (MSD) as well as to further develop its own pan-European marine assessments (Anon, 2006).

Below is a brief overview of biological elements covered by OSPAR, compared to requirements for biological elements under the Water Framework Directive and the proposed Marine Strategy Directive (Anon, 2006).

***OSPAR Common Procedure* -** Macrophytes including macro-algae; shifts from long-lived to short-lived nuisance species**.** Angiosperms and macroalgae are not used as indicators at the regional sea level but OSPAR does some monitoring in the context of its eutrophication assessment. OSPAR monitoring/reporting requirements for direct and indirect eutrophication effects under the Eutrophication Monitoring Programme (OSPAR agreement 2005-4) as part of the CEMP: Macrophytes, including macroalgae and angiosperms. Biomass, species composition, coverage, and reduced depth distribution (action required) (9). Annual monitoring of biomass and species composition of macrophytes (including macroalgae and angiosperms) in (potential) problem areas relating to eutrophication (applied as an assessment parameter). In OSPAR, where the parameter is monitored only for eutrophication problem areas and potential eutrophication problem areas; there are currently limited data available reported by Contracting Parties. National information is made available in the context of eutrophication assessments (2003 and 2008). Angiosperms are also used to evaluate the consequence of eutrophication.

***Water Framework Directive* -** The Water Framework Directive requires Member States to monitor angiosperms in transitional and coastal waters. For angiosperms, the most important parameter is distribution extension and variation in time and space (WDF Guidance Document). Monitoring frequencies are related to the degree of risk that a water body will fail to meet good ecological status.

Transitional waters: composition and changes in abundance of angiosperms.

Coastal waters: Presence of disturbance-sensitive macro-algal and angiosperm taxa. Macroalgal cover and angiosperm abundance**.**

***EU Marine Strategy Framework Directive* –** The MSFD requires as an element of the initial assessment a description of the biological communities associated with the predominant habitats. This could include information of

- The typical phytoplankton and zooplankton communities including the typical species, seasonal and geographical variability and estimates of primary and secondary productivity;
- The invertebrate bottom fauna including species composition, biomass, productivity and annual/seasonal variability

The structure of fish populations including the abundance, distribution and age/size structure of the population.

***Global biodiversity monitoring* -** Under the CBD no specific monitoring is required. The state of the marine environment will be evaluated through a global assessment, based on regional assessments.

Synergies with monitoring of other species or habitats

Nutrient concentrations and light attenuation in the water column are the most important water quality parameters affecting seagrass growth. Another habitat characteristic, salinity, may also play a role. These variables therefore constitute the primary list of variables to measure in connection with seagrass monitoring programmes. Knowledge on sedimentation rate of total and organic suspended particles will also help to assess the status of seagrass meadows. These parameters are measured in monitoring programmes of eutrophication.

Trends in seagrass health can act as alarm indicators of trends in the environment, since health of seagrass meadows is closely linked to the health of the wider marine environment (Borum *et.al.,* 2004).

The proposed monitoring system includes monitoring of seagrass distribution and abundance from coarse assessments of presence/absence or area distribution of seagrasses in large areas (with remote sensed data) to fine-scale diver assessments of depth limits and of cover, biomass or shoot density along depth gradients. These indicators all respond to changes in water quality. The lower depth limit of seagrasses and their abundance in deep water are the indicators most directly coupled to water clarity as they are primarily light regulated. These indicators should therefore have high priority in monitoring programs aimed at assessing effects of changes in levels of eutrophication and siltation. Seagrass abundance and area distribution in shallow water are more subjected to physical disturbance like wind- and wave exposure and sediment redistribution, and by human impact. Area distribution of entire seagrass populations therefore responds less predictably to changes in water quality than do deep populations, but distribution maps have the advantage of providing large-scale overviews of entire populations and are useful and easily eligible supplements to the more detailed monitoring (Borum *et.al.,* 2004).

Proposed assessment criteria

Assessment criteria for the whole OSPAR region are probably not possible to determine, since the variation in seagrass meadows and in associated fauna among the different regions is large. Below are two examples from the intercalibration work under the Water Framework Directive. The suggestion is to use the same assessment in OSPAR. One example is also given of classification from Sweden, from the Swedish Environmental Protection Agency, based on the basis for forming a judgement for environmental quality, with complementary addition from the research programme MARBIPP (2006). At the end an indicator table is given with suggestions on monitoring at different status.

Work under the Water Framework Directive: Under the WFD intercalibration between countries is carried out. Below are examples of agreed scheme on abundance, species composition, bed extent and depth limit of intertidal seagrass area (WFD technical report, 2008; Draft Milestone 6 report – Baltic sea GIG, 2007). The boundaries have been agreed by experts representing all countries in the GIG angiosperms sub-group.

The Netherlands, Ireland and the UK have agreed a common matrix for allocating status to intertidal seagrass assessments on the basis of the table below. This matrix combines both loss of species and degradation in the % cover (measured as the number of seagrass shoots in a quadrat or % cover of seagrass within a quadrat). The matrix covers both situations where naturally either two or three species of seagrass are found within either a type or where there are differences within types in specified geographic areas. The appropriate selection from the matrix is made at the waterbody level (WFD technical report, 2008, Draft Milestone 6 report – Baltic sea GIG, 2007).

Table 2. Intertidal Seagrass: Abundance and Species composition classification boundary matrix (WFD technical report, 2008)

Density (% cover)		0 - 10% lost	10 - 30 % lost	30 - 50% lost	50 - 70% lost	>70% lost
Species	No spp. lost	High	Good	Moderate	Poor	Bad
	1 spp. lost, 2 remain	Good	Good	Moderate	Poor	Bad
	1 spp. lost, 1 remains	Good	Moderate	Poor	Bad	Bad
	2 spp. lost, 1 remains	Moderate	Moderate	Poor	Bad	Bad
	All spp. lost, therefore 0% cover	Bad				

Intercalibration on angiosperm depth limit between Denmark and Germany for the type B12 has also been performed. The Danish Government has defined the good/moderate boundary as a 25 - 30% deviation from reference levels. In Germany the historical depth limit of *Zostera marina* was assessed as 10 m for stands, while for single plants few records of deeper occurrence exist (down to 17 m). Also in Denmark 10 m is assumed as the historical depth limit (Draft Milestone 6 report – Baltic sea GIG, 2007).

Schories *et al*. 2006 have defined for the German coast the eelgrass depth limit for good status to 7.0 - 8.0 m and moderate status to 4.5 – 7.0 m for the intercalibrated type B12 (German type B3) with an application of the Danish 90% rule to historical data, these values show a good fit to the Danish boundaries (Krause-Jensen 2005).

Table 3. Intertidal seagrass area (acreage/bed extent) classification boundary values and eelgrass depth limit for good status (WFD technical report, 2008; Draft Milestone 6 report – Baltic sea GIG, 2007).

Description of seagrass		**High**	**Good**	**Moderate**	**Poor**	**Bad**
Seagrass beds	Change in area[1]	0 - 10% loss	11 - 30% loss	31 - 50% loss	50 - 70% loss	>70% loss
	Depth limit of Zostera stands[2]	0 – 6 % reduction from reference	6 – 10 % reduction	10 – 30 % reduction	30 – 80 % reduction	80 - 100 % reduction

Classification of quality: Below is one example of classification from Sweden, from the Swedish Environmental Protection Agency, based on the basis for forming a judgement for environmental quality, with complementary addition from the research programme MARBIPP (2006). The limits of depth penetration, biomass and key fauna used in assessment need to be adapted locally or regionally. As an example the key fauna on the west coast of Sweden is *Gammarus locusta* but on the Swedish east cost the key fauna used is *Isopoda* spp. and *Gammarus* spp.

SHELTERED EELGRASS MEADOW IN SKAGERRAK AND KATTEGATT

Class	Name/term	Description
1	Insignificantly influenced	*Zostera marina* common down to 8 m depth Above ground biomass of *Zostera marina* is approximately around 400 g dryweight/m^2 No occurrence of filamentous algal mats Adult *Gammarus locusta* are numerous (100 indiv./m^2)* Very high quantity of seagrass associated fauna
2	Slightly influenced	*Zostera marina* common down to 6 m depth Above ground biomass of *Zostera marina* is approximately around 200 g dryweight/m^2 Small sporadic occurrence of filamentous algal mats Adult *Gammarus locusta* common (50 indiv./m^2)* High quantity of seagrass associated fauna

[1] Draft Milestone 6 report – Baltic sea GIG, 2007

[2] Schories et.al.2006

3	Clearly influenced	*Zostera marina* common down to 5 m depth Above ground biomass of *Zostera marina* is approximately around 100 g dryweight/m^2 Large filamentous algal mats are common, sulphur bacterium occurring Adult *Gammarus locusta* are rare (‹10 indiv./m^2)* Reduced quantity of seagrass associated fauna
4	Strongly influenced	No *Zostera marina* deeper than 3 m depth Separate plants of *Zostera marina,* aboveground biomass less than 50 g dryweight/m^2 Filamentous algal mats dominate the bottom, sulphur bacterium common No adult Gammarus locusta Low quantity of seagrass associated fauna
5	Society eliminated	No or very little living *Zostera marina* No or very few seagrass associated fauna The bottom is dominated of filamentous algal mats or mats of sulphur bacterium, or the sediment is naked and exposed to erosion

* The meadow can be uninfluenced even if *G. locusta* is absent. A very high number of *G. locusta* (› 500/m^2) can also indicate a disturbed system.

Suggestion of indicators: Monitoring programmes can benefit from including variables on habitat quality in addition to seagrass indicators. Such variables affect the seagrasses, and information on their level may therefore help identify reasons for status and changes in seagrass indicators and suggest corrective measures. The table below show suggested indicators for basic and enhanced monitoring and suggestion at what status the enhanced monitoring (on habitat quality) could be required. It is important to use the same limits as in relevant EU directives, Zostera beds are considered in the Water Framework Directive as a reference habitat to evaluate the biological quality of a watermass (Hily, 2003).

Table 4. Suggested indicators for basic and enhanced monitoring and at what status the enhanced monitoring is required.

Indicator	Basic Monitoring	Enhanced Monitoring	Status
Presence/absence	X		High-Good
Cover	X		High-Good
Seagrass species	X		High-Good
Depth limit	X		High-Good
Biomass		X	Moderate-Poor
Shoot density		X	Moderate-Poor
Filamentous algae		X	Moderate-Poor
Abundance of epiphytes		X	Moderate-Poor
Key fauna		X	Moderate-Poor

Techniques/approaches

Baseline monitoring programme

Indicators of seagrass distribution

Presence/absence and area distribution of seagrasses are commonly used indicators of status and change in seagrasses at the landscape scale. Presence/absence is the simplest of all seagrass indicators.

i) Presence/absence and area distribution of Zostera beds

Definition: A seagrass meadow is defined when seagrass cover a bigger area than 2x2 meter, when patchy it is still a meadow if it is less than 10 meters between the patches, if bigger than 10 m between patches it should be counted as a new meadow (MARBIPP 2006).

Method description: Presence/absence and area distribution of seagrasses can be assessed using various methods of seagrass mapping, ranging from diver observations or survey using aqua scope and differential GPS from a small boat to remotely sensed data from satellites or airborne sensors. In general areas of less than 1 ha (1:100) and up to 1 km^2 (1:10,000) can be investigated by divers, aquascope or drop down video, but in larger areas the remote sensing methods are more appropriate. Aerial photography is the most common remote sensing method for seagrass mapping studies and for monitoring over time, while satellite data are valued for large-scale localisation investigations (Borum et.al. 2004).

In clear shallow waters with seagrasses occurring on a light, sandy bottom, the contours of the meadows can easily be distinguished in remotely sensed images such as aerial photos. Ground surveys, are essential to make sure that other underwater features such as macroalgae, reefs or mussel banks are not mistakenly identified as seagrass meadows. Ground surveys alone, however, are often too costly and inconvenient for mapping large coastal areas. Short and Coles (Short & Coles, 2001) gives a summary of available and appropriate techniques for mapping seagrasses in areas of different size and water depth.

Method evaluation: The choice of method depends on the purpose of the monitoring. When the objective is to catalogue the presence/absence of seagrasses or coarsely assess the area distribution, the choice is for macro-scale maps of low resolution. By contrast, when the objective is to provide detailed data on distribution and change in seagrass areas or to estimate the biomass, the best choice is high-resolution maps. If a finer scale mapping is necessary, a differential GPS can be used to delineate at patch level. Results from the assessment can be visualized in maps showing changes in seagrass distribution. These maps can be created in e.g. ArcView, a geographical information system (GIS) program, which also can be used for calculation of seagrass changes (Gullström, 2006).

Explanation: Status and changes in seagrass beds are important in order to overview the extent of decline and recovery. Presence and area distribution of seagrasses may be reduced by human impact. Eutrophication primarily increases shading because of phytoplankton blooms and increased growth of epiphytes and thereby reduces depth limits, abundance and area distribution of the seagrasses. Physical impact, such as construction of harbours and dredging, have more direct and drastic effects at least in the directly impacted areas (Borum *et.al.* 2004).

ii) Colonisation depth of Zostera

Colonisation depth is one of the best-known seagrass indicators of water quality, due to its well-described relationship with water clarity and the relative ease with which it can be estimated precisely.

Definition: Colonisation depth is defined as the maximum water depth at which seagrassess grow. The maximum depth of well-defined meadows or as the depth of the deepest growing shoots (Borum et.al. 2004).

Method description: Colonisation depth can be determined by scuba diving or drop down video along a depth gradient to the maximum depth of the population. Several subsamples (e.g. with transects) within each site and coastal area are needed due to the considerable variation (Borum *et.al*. 2004). Instead of having one observation per depth gradient, the diver may swim along the lower limit of the meadow and record depth limits at several points (7-10 observations of each transect is recommended in the Danish monitoring programme) (Krause-Jensen *et.al*. 2005). The diver records the depth limit using a high-precision depth recorder. The water depth must be corrected to average water levels. Determination should be carried out in the growth season and preferably at the same time of the year in multi-year comparisons.

Method evaluation: Depth limits can be estimated with relatively high precision if good depth sensors are used and if water depth is corrected depending on the tidal level at the sampling time. Other advantages are that the method is non- destructive and allows repeated measurements at the same location. It must be clear, however, whether sampling refers to the depth limit of meadows or of individual shoots and, if the former is the case, the depth limit must be defined precisely e.g. as the maximum depth where seagrasses cover a given fraction (e.g. 10%) of the bottom (Borum *et.al*. 2004).

Monitoring frequency: It is recommended to follow the meadows at the same time in several years, due to the large variation between years (MARBIPP 2006).

Explanation: The depth limit is primarily determined by water clarity, and hence closely related to nutrient levels. Danish investigations reveal that between 1900 and 1990 maximum colonisation depths in Denmark decreased from 5-6 m in estuaries and 7-8 m in open waters, to 2-3 m and 4-5 m, respectively (Boström et.al. 2003). Only about 25% of the former areal extension was left in 1990. This reduction is partly caused by losses of deep eelgrass stands as a consequence of poorer light conditions and partly to the slow recovery after the seagrass disease in the 1930´s. A large compilation of data from Danish coastal waters demonstrated that eelgrass depth limits increase significantly as nitrogen concentrations decline and water clarity increases. Similar trends have been shown for other sea grass species in a worldwide compilation (Draft Milestone 6 report, 2007).

Indicators of seagrass abundance

The abundance of seagrasses shows a characteristic depth dependence, the highest abundance typically being found at intermediate water depths where levels of exposure and light are moderate. The decline in seagrass abundance from the depth of maximum abundance towards greater water depths depends, at least partly, on light attenuation in the water column and is therefore sensitive to changes in water quality (Krause-Jensen et.al. 2003). As seagrass abundance changes markedly on an annual basis, it is important for all indicators of abundance that comparisons between years are based on samplings performed at the same time of the year, at biomass maximum. Seagrass abundance can be measured as cover, biomass and shoot density.

i) Cover

Seagrass cover describes the fraction of sea floor covered by seagrass and thereby provides a measure of seagrass abundance at specific water depths. Depending on sampling strategy, seagrass cover may reflect the patchiness of seagrass stands or the cover of seagrass within the patches, or both aspects.

Definition: The fraction of sea floor covered by seagrass, measured as cover of seagrass leaves on a 0-100 % scale.

Method description: As cover is depth dependent, any measure of cover must be related to water depth. The study area can be either coarsely defined as a corridor through which the diver swims, or be more precisely defined as quadrates of a given size. Percent cover of seagrasses is usually estimated visually by a diver as the fraction of the bottom area covered by seagrass. The cover can be estimated directly in percent or assessed according to a cover scale. A recommendation is to standardize the estimates using an existing guide or by making a photo calibration guide with photos on representative quadrats from 1-100% (Duarte & Kirkman, 2001).

In the Wadden Sea (Waddensea Report, 2006) three categories are recognized based on occurrence of seagrass and the methods applied for their assessment:

1. Areas may be entirely devoid of seagrass or may have a few isolated plants with coverage <5%.
2. Areas may show growth of scattered seagrass plants when at peak vegetation period average cover is between 5 and 20%.
3. In addition or instead, areas may show seagrass beds with >20% cover at peak vegetation period.

Beds have either a coherent coverage of >20% or are composed of clusters of patches (with >20% coverage) less than 25 m apart.

In the Danish national monitoring programme, eelgrass cover is assessed within corridors of about 2 m along depth gradients. A diver swims along the depth gradient and estimates percent cover at intervals of 5-10 m along the depth gradient. The diver uses underwater communication, and the regular observations of cover are recorded on the boat together with automatically logged information on position and water depth. Based on the raw data, the average cover within depth-intervals of 1 m is calculated. This method of assessing cover was found to be the most repeatable, precise and cost-efficient of several methods tested (Borum *et.al.* 2004).

Method evaluation: Visual estimates of percent cover is a simple, non-destructive way of quantifying seagrass abundance. Cover estimates are coarse but well suited for surveys at the landscape level. It is however a risk that they may be made subjectively, as cover estimates are based on visual observation and it is important, therefore, that the divers making them are trained.

Explanation: Light climate and exposure levels are the main factors regulating seagrass cover along depth gradients. Seagrass cover is a more sensitive indicator of eutrophication at intermediate water depths and in deep water, where light plays a major regulating role, than in shallow water, where physical exposure has a marked influence. Both shoot density and shoot length affect this estimate and, consequently, meadows consisting of dense, short shoots may have the same cover as meadows of sparser but longer shoots. Cover is therefore less sensitive to changes in light climate than is shoot density (Borum *et.al*. 2004).

ii) Biomass of Zostera

The indicator is useful for detailed analyses of changes in seagrass abundance. The method can also be used in connection with area distribution measures to estimate the standing stock of seagrasses in a given area (Borum *et.al*. 2004).

Definition: Biomass is the weight (dry weight, fresh weight or ash-free dry weight) of *Zostera* leaves per unit area (m^2) and thereby provides a measure of seagrass abundance along depth gradients

(MARBIPP 2006). The measure refers to either the total biomass or the aboveground biomass of the seagrasses.

Method description: Biomass is measured by divers harvesting either the aboveground or the total biomass of seagrass within sampling frames. It is recommended that samples be taken randomly within stands rather than including samples from bare areas, because this sampling strategy reduces the variability of the estimates (Borum et.al. 2004). Some sampling programmes even recommend that samples be taken randomly within the densest stands, others recommend standardized depth (e.g 2-4 m), in order to reduce the variability further (MARBIPP 2006). The number of sub-samples and monitoring sites needed depends on the spatial variability of seagrasses in the area. In the laboratory, the samples are rinsed, dried to constant weight, weighed and related to the area of the sampling frame. As biomass is depth dependent, any measure of biomass must be related to water depth.

Method evaluation: The method provides a relatively precise measure of seagrass abundance, and is repeatable if the sampling strategy is well defined. The method has the disadvantage of being destructive (the aboveground biomass is less destructive) and is relatively costly, requiring sampling in the field as well as subsequent laboratory work (Borum et.al. 2004). The between-year variation is often large and therefore it is recommended to carry out measurements for at lest three years (Duarte & Kirkman, 2001).

Explanation: Biomass is a measure of seagrass abundance along depth gradients, which are related to water clarity. Changes in the seagrass meadow will likely be shown by changes in biomass (Duarte & Kirkman, 2001). Seagrass biomass tends to decline exponentially from the depth of maximum abundance towards the depth limit, thus paralleling the decline in light availability with increasing depth.

iii) Shoot density

The clear exponential decline in maximum shoot density with depth suggests that shoot density responds faster than biomass and cover to changes in light climate and consequently is the more sensitive of the seagrass abundance indicators. It should therefore be possible to forecast seagrass shoot density under future water quality regimes with higher precision than cover and biomass (Borum et.al. 2004).

Definition: Shoot density is the number of seagrass shoots per m^2 and thereby provides a measure of seagrass abundance along depth gradients.

Method description: Shoot density can be measured in connection with biomass measurements by counting the number of shoots in the harvested samples before the samples are dried (see above). Shoot density can also be measured in a non-destructive manner by counting the number of shoots within given sub-areas in the field. As shoot density is depth dependent, any measure of shoot density must be related to water depth.

Method evaluation: The method provides a relatively precise measure of seagrass abundance. Counting shoots in harvested samples requires less laboratory work than processing of biomass samples but the method is still relatively time-consuming. Counting shoots in the field increases the sampling time in the field but requires no laboratory work. As shoot density of eelgrass in shallow water may amount to about 2500 shoots per m2, counting dense stands in the field is only feasible if small sub-areas are used. In addition shoot counts are not practical to monitor in Zostera noltii meadows, where small shoots occur at great densities (several thousand per m2). Duarte and Kirkman (Duarte & Kirkman, 2001) suggest different size of the frames depending on the anticipated shoot density: 0.5 m x 0.5 m for less than 300 shoots m-2, 0.25 m x 0.25 m for 300-3000 shoots m-2 and 0.1 m x 0.1 m for more than 3000 shoots m-2.

Explanation: The maximum shoot density at given water depths shows a clearer exponential decline with depth than do biomass and cover, indicating that shoot density is regulated in a more direct and deterministic manner than the other abundance variables (Borum *et.al.* 2004).

Enhanced monitoring programme

Indicators of seagrass quality

Seagrass monitoring programmes can benefit from the inclusion of observations of habitat quality in addition to seagrass indicators. Relevant variables and their condition may therefore help identify reasons for status and changes in seagrass indicators and suggest corrective measures.

i) Presence and amount of filamentous algae

Macroalgal blooms may be an obvious component of seagrass ecosystems when ambient nutrient concentrations are high.

Definition: Abundance of filamentous algae, either as cover (%) or as biomass (dry weight, fresh weight or ash-free dry weight) per unit area (m^2).

Method description: The abundance of macroalgal blooms can be measured either as cover or as biomass using the same methods as described for seagrasses. Percent cover of the seafloor of filamentous algae can be measured either with aerial photo or by using quadrates randomly placed at the sample sites (Gullström, 2006).

Method evaluation: Macroalgal blooms may vary markedly over time both because they grow fast and because it is regulated by wind exposure and can be decimated after a storm. Sampling must therefore be repeated several times during the growth season to represent the site properly (Borum et.al. 2004).

Explanation: The amount of filamentous algae can be used as a proxy of nutrient richness in coastal waters. The presence of the genera *Ulva, Calophora* and *Enteromorpha* which thrive under nutrient rich conditions can be used as an indicator of deterioration of sediment quality for seagrass growth. Eutrophication-gained filamentous algae (mainly ephemeral) may shade seagrasses, hamper water exchange and cause a decline in associated faunal communities, e.g. shrimps and crabs (Borum *et.al*. 2004). In shallow stagnant waters with limited oxygen pools, as well as in deeper stratified waters, the oxygen-consuming decomposition of ephemeral algae and detritus may lead to anoxia and formation of hydrogen-sulfide in the bottom sediment (18). High water temperature also stimulates microbial decomposition rates and thereby further increases the risk of anoxia (Boström *et.al*. 2003).

ii) Abundance of epiphytes

Epiphytes may be a prominent component of seagrass ecosystems when ambient nutrient concentrations are high.

Definition: Abundance and species composition of seagrass epiphytes.

Method description: Sampling shoots with associated epiphytic assemblages with a net bag attached to a frame. The epiphytes are rinsed from the shoots, taxonomically identified and the dry weight is measured (Gullström, 2006). Details on methods for sampling epiphytes can be found in e.g. Borum (Borum, 1985).

Method evaluation: Sampling of epiphytes is costly. Epiphytic biomass may vary markedly over time both because the organisms grow fast and because epiphyte biomass is regulated by wind exposure and can be decimated after a storm. Sampling must therefore be repeated several times during the growth season to represent the site properly (Borum et.al. 2004).

Explanation: Epiphyte abundance and species composition in seagrass meadows can be used as a proxy of nutrient richness in coastal waters (Borum et.al. 2004).

iii) Key fauna

Seagrass meadows host a large number of animal species. Information on the fauna species associated with seagrass meadows often reflect plant health and may also add to the general understanding of the importance of seagrass beds for coastal biodiversity. Relevant key fauna to measure in connection with seagrass monitoring programmes may differ between regions, but examples are:

- Fish – there are fish species that are "permanent residents" in the seagrass meadows. Examples are pipefish and sea sticklebacks. Exclusive feeding on living seagrass leaves is rare; in general fishes that feed fresh leaves also depend on other food resources, such as epiphytes or small invertebrates (Borum et. al., 2004). Number of species and quantity of each species of fish e.g gadoids (cod, whiting and saithe), labrids (goldsinny, wrasse and corkwing), syngnathids (great pipefish and snake pipefish) and two-spotted goby could be measured (29). Fish can be sampled with underwater visual census or quantitative with gill net or drop nets. The investigations should be carried out when the fish community has the largest species richness and highest abundance and biomass, both during the day and during the night (MARBIPP 2006, Pihl et.al. 2006).
- Grazers - new results (from the research programme MARBIPP) suggest that small invertebrate grazers (the amphipod *Gammarus locusta)* can control the abundance of filamentous algae in *Zostera* meadows, also during nutrient enrichment, if their biomass passes a critical level (50-100 individuals/m^2). However, a huge amount of small epibenthic predators can keep the grazing community below this level. Number of the grazer *Gammarus locusta* can be calculated by quantitative catch in a trap or bag net (MARBIPP 2006). In many beds of the Western Europe the dominant micrograzers are gastropods (Gibbula spp, Jujubinus spp, Onoba, and Rissoidae) which also can control the epiphytic biomass (Hily et.al. 2003).
- Birds – can be major seagrass consumers in the intertidal zone, e.g. the mid-west
- European coastal areas, with *Zostera marina* and *Z. noltii* populations are
- wintering areas of some species of birds: brent goose, pintail, widgeon and mallard. Swans also graze on seagrasses (Borum et.al. 2004). The abundance of birds can be assessed by population density surveys.
- The underwater visual census is a quantitative estimation of the abundance of fishes and large epibenthic invertebrates by transects in clear water environments. There are other techniques available for assessing the abundance and biomass of fishes and epibenthic invertebrates, such as gill nets, drop nets, etc., in turbid waters (Borum et.al. 2004).

Indicators of the environment

i) Water quality and climatic variables

Nutrient concentrations and light attenuation in the water column are the most important water quality parameters affecting seagrass growth. Another habitat characteristic, salinity, may also play a role. These variables therefore constitute the primary list of variables to measure in connection with seagrass monitoring programmes (Borum *et.al*. 2004):

- *Light attenuation* – can be measured simply by using a Secchi disc or more precisely using a light meter to measure actual light levels at different positions in the water column and then calculate the light attenuation per meter water column.
- *Nutrient concentrations* – inorganic concentrations are often low and difficult to detect in summer so it may be a better choice to measure inorganic nutrient concentrations in winter and/or total nutrient concentrations in summer.
- *Salinity* – can e.g. be measured automatically using a probe or using a refractometer.

ii) Sedimentation

Human activities in the littoral zone increase the inputs of organic matter to the sediment and the growth and survival of seagrasses decrease as this input increases. Knowledge on sedimentation rate of total and organic suspended particles will help to assess the status of seagrass meadows. The rate of suspended particle deposition on seagrass sediments can be measured by deploying benthic sediment traps (Borum et.al. 2004). Details on sampling methods can be found in e.g. Gacia *et al*. (Gacia *et.al*. 2003).

Selection of monitoring locations

In order for the monitoring to be efficient in detecting possible changes in seagrass distribution and abundance it is important that the variability of the estimates is as low as possible. The lower the variability of the estimate, the smaller the identifiable year-to-year differences in seagrass parameters. If the sampling area contains gradients, e.g. a nutrient gradient from inner towards outer parts of an estuary, a stratified sampling design may help reduce the variability of the sampling results (Duarte & Kirkman, 2001). A stratified sampling design infers that sampling sites are distributed within separate strata in the sampling area, e.g. in inner, central and outer parts of the estuary and that sampling results are calculated as means for each stratum rather than being calculated as means for the entire estuary. At random sampling, for example when estimating biomass, it is recommended to use small quadrat samplers with many replications (Duarte & Kirkman, 2001). It may be an advantage to conduct random sampling within depth strata because many seagrass parameters change markedly with water depth. Eelgrass has the maximum abundance at intermediate depths and lower abundance in shallow and deep waters (Borum et.al. 2004).

The optimal number of sites and subsamples to include in a monitoring programme depends on the variability in seagrass parameters in the area. In areas showing large variability within sampling sites as compared to among sites, a sampling strategy involving few sites with many subsamples each will be an advantage. In contrast, many sites with few subsamples each are appropriate if the between site variation is large relative to the within site variation (Borum et.al. 2004).

Timing and Frequency of monitoring

Timing

Zostera beds have wide but patchy distribution and are naturally dynamic. Perennial populations show seasonal changes in leaf growth, the long leaves found in summer are replaced by shorter, slow growing leaves in winter. In Sweden there are usually only the roots in the sediment left in the winter. The morphological characteristics, especially leaf width may vary with environmental conditions (Tyler-Walters, 2007; MARBIPP 2006). Mapping of seagrass presence and abundance should therefore be performed at the annual biomass maximum and preferably at the same time of the year in multi-year comparisons. The peak vegetation period varies between regions, but is probably somewhere between July to September in the OSPAR region.

Frequency

A newly performed Swedish study (as investigations in the research programme MARBIPP) showed that it was a big difference in cover of seagrass between years, both within a meadow and within a region. Some seagrass meadows that were nearly absent one year were big and healthy the year after. Also studies in the Wadden Sea shows that seagrass bed dynamics are high (van Katwijk et.al. 2005). These results show that the changes within a meadow between years are much bigger than we have known before. It is thus very important to monitor occurrence in a region by following the development of many meadows during several years. Important to accentuate is that even if there is no eelgrass in the bay one year there can be eelgrass there the next, therefore also potentially eelgrass biotopes need to be invented (MARBIPP 2006; Reise et.al. 2005).

The relevant monitoring frequency depends on potential impacts to the ecosystems and their health status. In highly impacted systems mapping should be done relatively often, e.g. once a year, whereas in weakly impacted systems a mapping interval of 5-10 years may be sufficient (Borum et.al. 2004). For multi-year comparison it is important to follow the meadows and potential meadows in several years, due to the large variation between years (MARBIPP 2006). The time it takes to determine real changes caused by human disturbances may however take 5-10 years (Duarte & Kirkman, 2001).

In the Wadden Sea a complete and concerted ground survey throughout the Wadden Sea about every 10 years is suggested. In addition, 30 to 50 sites will be selected for detailed analyses of population developments. This number is assumed to be necessary to take into account the diverse habitat types under which *Z. noltii* and *Z. marina* are growing or may potentially grow. The purpose is also to include potential sites for which actual records of seagrass are lacking. On the other hand, the preference is to monitor at a high temporal resolution but in fewer sites compared to monitor every 2-3 years at more sites. They also suggest that a basis is needed to quickly detect changes in seagrass development during vegetation periods. Measurements of a wide spectrum of growth characteristics have the potential to provide a clue to possible causes of change (Reise et.al. 2005).

In areas with no knowledge about the distribution and status of the *Zostera* beds one suggestion is to start monitoring with an intense sampling to conduct a baseline assessment and thereafter when variability is known decide and continue with a full monitoring programme. The Irish Government has been conducting such a baseline assessment of the subtidal distribution, extent and condition of *Zostera,* including inventory of associated fauna, since 2004. The baseline programme will finish in 2009. Thereafter, a full monitoring programme will be implemented (Kelly, pers.com).

Data collection and reporting

Data recorded from the samplings should include date, time, site or transect description, quadrat size, number of replicates, GPS location, tide condition and water depth. Below is an example of an inventory format slightly modified after a format for the monitoring in the Wadden Sea for Denmark (TMAP, 2006).

	Country
1. General	
1.1 Institutes	
1.2 Title	Sea grass monitoring
1.3 Aim	Documentation of the development of sea grass *Zostera marina* and *Z. noltii*
2. Sites	
2.1 Area and frequency	• Mapping area • Frequency and time of the year
2.2 Parameters	Basic: • Location of seagrass beds: coordinates of seagrass beds (GIS polygon), • Coverage of seagrass-species: Seagrass coverage of the beds (%) • Area: size of seagrass beds (km²) • Deph limit: single shoots or bed extent (m) Additional: • Biomass of seagrass species per unit area (m^2) • Number of seagrass shoots per m^2 • Cover (%) or biomass (per $m^{2)}$ of eutrophication-related algea (e.g. *Chaetomorpha linum, Cladophora sp., Enteromorpha sp., Ulva lactuca, Ulvaria fusca, Ectocarpus sp., Pilayella sp.)* • Species composition (*Zostera marina* and Z. noltii,)
2.3 Methods	• Remote sensing • Ground survey/Field mapping, GPS (transects, sampling plots) Field surveys should be carried out: - as ground truth in conjunction with remote sensing - to monitor areas with scattered occurrence of seagrass (<20% coverage) including potential seagrass areas. - to get more detailed information (quantitative and qualitative) to be able to characterize the ecological status of the seagrass beds. The surveys should be carried out during peak vegetation period (mid of July to mid September).
2.4 Analyzing methods	
3 Data handling	All data obtained from aerial and field surveys should be transferred to a geographical information system (GIS) for the analysis and assessment of the data (spatial and temporal development) and in combination with other GIS based information.
4 Quality assurance	Appropriate monitoring protocols should be developed on national level. Intercalibration exercises should be carried out nationally and in the framework of OSPAR

Quality assurance

(Source: Manual for Marine Monitoring in the COMBINE Programme of HELCOM)

A sampling programme should include the following:

1. a predetermined sampling plan that takes into account the specific purpose of the investigations, including the parameters to be determined, and the type of analyses to be performed;
2. sample collection by personnel trained in the sampling techniques and procedures specified;
3. maintenance of the sample integrity by using sampling devices that have been found to be suitable for the particular purpose, avoiding confusion of samples
4. using transportation procedures that ensure that the composition of the sample or the concentrations of the variables are not altered;
5. instructions for labelling the sample specifying its identity;
6. a record that demonstrates an unbroken control over the sample from collection to its final disposition.

Necessary documentation includes:

- a clear description of sampling equipment
- a clear description of all steps in the sampling procedure
- a clear description of the methods used
- protocols for sample identification and analyses
- clear labelling of samples and signature of the person responsible

Appropriate monitoring protocols need to be developed on national level. It is suggested that intercalibration exercises be carried out nationally and in the framework of relevant EU directives.

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