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Towards ecological coherence of the MPA network in the Baltic Sea

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BALANCE

Towards an Assessment of Ecological Coherence of the Marine Protected Areas Network in the Baltic Sea Region.	BALANCE Interim Report No.
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CONTENTS

0 EXECUTIVE SUMMARY

Networks of marine protected areas (MPAs) are recognized as a powerful tool to sustain the viability of marine biodiversity. Coherent networks of marine protected areas are needed to protect valuable habitats, to support species that use these habitats as feeding or breeding grounds, and to make the ecosystem more resilient to external threats like eutrophication, invasive species or climate change.

Ecologically coherent networks of marine protected areas are also required by many international conventions. All EU member states are obliged, by the EU Habitats and Birds Directives (EC Birds Directive 1979, EC Habitats Directive 1992), to designate Natura 2000 sites to ensure favourable conservation status of habitats and species listed in the Annexes I and II of the Habitats Directive and Annex I of the Birds Directive. Sites designated under the Habitats Directive are referred to as Special Areas of Conservation (SACs) and the sites designated under the Birds Directive as Special Protection Areas (SPAs). According to article 3 in the Habitats Directive, the Natura 2000 sites should together form a *coherent* network of protected areas. The initial assessment of ecological coherence of the network should be done by 2008. Also, the Ministerial Declaration of the Joint Ministerial meeting of the HELCOM[1] and OSPAR[2] in Bremen 2003 states that, by 2010, an ecologically coherent network of marine protected areas should be established in the Baltic Sea and the North East Atlantic. This network should include Baltic Sea Protected Areas (BSPAs) in the Baltic Sea and Marine Protected Areas in the North East Atlantic, including the Natura 2000 network. According to the Ministerial Declaration, the first assessment of ecological coherence of the network should be done in 2010. Both HELCOM and OSPAR have taken initiatives to develop criteria for assessing ecological coherence of their networks. A preliminary assessment of the ecological coherence of the BSPA network has also been done by HELCOM, whereas the Natura 2000 network has so far not been assessed.

The aim of the work presented in this report was to develop practical criteria and a first set of tools that can be used repeatedly to assess ecological coherence of the Baltic Sea MPA networks. A further aim was to use these tools to make the first preliminary assessment. The work was carried out within BALANCE, an Interreg IIIB-funded project involving 19 partners around the Baltic Sea that aims to develop informed marine management tools based on spatial planning.

We adopted four central criteria for an ecologically coherent network from scientific literature and previous work e.g. in OSPAR and HELCOM. In order to be ecologically coherent the network should 1) be **adequate** in terms of MPA size, shape and quality to fulfil its aims, 2) ensure **representation** of the full range of conservation features (species, habitats or landscapes) in a region, 3) include **replicates** of each feature to ensure protection of the natural variation of the features it aims to protect and to give insurance against catastrophic events, and 4) ensure **connectivity** by enabling dispersal and migration of species within and between MPAs.

[1] Helsinki Commission, the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area" - commonly known as the Helsinki Convention.
[2] Oslo-Paris Commission, the governing body of the 1992 OSPAR Convention.

Within the BALANCE project these theoretical criteria were further developed into more practical ones that were used to assess the Baltic Sea MPA networks. When assessing the Natura 2000 network, our primary aim was to look at the SAC network, which aims to protect benthic habitats. However, the assessment also includes a component where the SPAs have been added to the SAC network. This approach was chosen to discover whether the designation of SPAs also as SACs would improve the ecological coherence of the Natura 2000 network, as designation of SPAs also as SACs would most likely be easier in practice than designation of new unprotected sites. In addition, the assessment was also carried out for the BSPA network.

The assessment of ecological coherence of the Baltic Sea MPA networks was done on a broad-scale for the entire Baltic Sea based on marine landscape maps developed in the BALANCE project. Marine landscapes are geophysically defined areas of the sea bottom or water column that can be used as proxies for biological communities when lacking biological data. In this assessment we used benthic marine landscapes that were defined by bottom substrate, salinity and photic depth.

A finer scale assessment of the Natura 2000 network was carried out in a pilot area, the Swedish archipelago - Åland Sea - Archipelago Sea, based on modelled habitat maps of six Natura 2000 habitats listed in Annex I of the Habitats Directive. The habitat maps were all produced in the BALANCE project. This approach, though limited in spatial coverage, allowed development of more accurate criteria for the assessment, as well as assessing the Natura 2000 network by using the habitats that the network is actually aiming to protect. The assessment was also carried out for five essential fish habitats using habitat maps produced in the area.

At the Baltic Sea scale we found that both of the networks need to be improved in order to reach ecological coherence. The geographical distribution of both Natura 2000 sites and BSPAs is heavily biased towards coastal and shallow areas and only a few areas are found in the offshore and deeper areas. There is also a lot of variation in representation between the sub-regions of the Baltic Sea: the Bothnian Bay and the Bothnian Sea has the lowest representation. There is also high variation in representation between the different Baltic Sea countries where Germany is the only country with over 20% coverage of MPAs. As much as two thirds of the benthic marine landscape are represented to less than 20% within the networks. The networks are also heavily biased towards certain bottom types such as sand and hard bottoms, whereas mud and hard clay, particularly in the deeper non-photic zone, are poorly represented.

The size distribution of the SACs is heavily biased towards small sites (less than 100ha) and the inclusion of SPA sites to the network does not improve the situation. BSPAs, however, are generally larger. The number of replicates of landscape patches within the network is generally quite high, which most likely results from the natural patchiness of the Baltic Sea marine landscapes. However, many of the landscape patches are only partly protected and therefore may not be adequate in supporting viable communities of species. Furthermore, replicates of some landscapes are located only within a few protected sites and therefore the natural variation of the landscapes is most likely not covered by the protected area networks. It has been concluded that defining a replicate still needs further development and the adequate number of replicates needs to be set species-specifically.

The assessment of both networks indicated poor connectivity for short-distance dispersers (1 km dispersal distance), whereas it is better for long-distance dispersers (>25 km). The connectivity is highest for landscape patches in coastal areas where also most of the protected areas are situated. However, even for species with 25 km dispersal distance, highest connectivity often occurs within sites, not between sites. This is the case especially within the BSPA network that consists of relatively few large sites located relatively far from each other in some areas. However, securing connectivity also over larger areas (i.e. between sites) would be important. For short-distance dispersers the larger sites seem to be more efficient in securing connectivity as the protected landscape patches often form rather large connected clusters within the large sites. It should be mentioned that the assessment was carried out using only distance, meaning that the direction of currents and water movements important for species dispersal were not considered and that dispersal to all directions was allowed.

At the pilot area scale, ecological coherence was assessed only for the Natura 2000 network. The representation of the assessed Natura 2000 habitats within the network was found to be too low to indicate sufficient ecological coherence of the network. The poor representation of the Natura 2000 habitats was also reflected in the representation of essential fish habitats as many of the shallow vegetated habitats (e.g. *coastal lagoons, large shallow inlets and bays*) are also important recruitment areas for fish. The size distribution of the sites showed a similar pattern as the assessment at the whole Baltic Sea scale: a bias towards small sites (smaller than 100ha). The small size of the sites results in many of the habitats only being partly protected, as a minimum requirement for adequate protection would be that the whole habitat should be protected. Due to the natural patchiness of the Natura 2000 habitats, most of the habitats have relatively many replicates within the network, especially those that are relatively small and very numerous (*reefs, boreal Baltic islets and small islands* and *coastal lagoons*). However, as many of them are only partly protected they may not be of sufficient size to support viable communities of species. In some cases the replicates are also very unevenly distributed within the pilot area, and naturally the areas with no replicates severely affected the overall connectivity of the habitat. The connectivity assessments carried out using short dispersal distances again proved the importance of larger sites in supporting within-site connectivity of short-distance dispersers. Similarly, for the essential fish habitats it was found that connectivity of the Natura 2000 network is inadequate, as a consequence of the short migrations undertaken by the studied species.

The assessment carried out on the Baltic Sea scale showed that in order to reach ecological coherence of the Baltic Sea MPA networks, **more sites should be designated**, especially **in the deeper offshore areas** but also in the coastal areas. Also the **low salinity** areas in the Gulf of Bothnia, as well as **mud and hard clay landscapes** need substantially better representation within the network. At the Baltic Sea scale, the designation of SPAs as SACs would not significantly improve the ecological coherence of the network, but in some countries that have large SPAs, better coherence of the network could be achieved. There is also a clear need for **larger sites**. Designation of large sites would also support within-site connectivity of short-distance dispersers, which was recognized as a major shortcoming of the current network.

The more detailed assessment carried out in the pilot area showed that more emphasis should be set on placing the sites to cover whole habitat patches, not only parts of them. Especially for habitats that are generally larger (e.g. *estuaries*), larger sites need to be designated. Larger sites are also important, however, in securing within-site connectivity of species inhabiting smaller fragmented habitats (e.g. *reefs*). Overall, representation of all assessed habitats, both Natura 2000 and essential fish habitats, should be increased and when doing this, emphasis should be set on placing the new sites in areas where the particular habitat has not been protected. This would not only secure natural variation of the habitat, but also improve connectivity between the protected habitats.

The strengths and weaknesses of the current Baltic Sea MPA networks reflect the aims and the guidelines set in the "driving forces" for their designation i.e. the Habitats Directive and HELCOM Recommendation 15/5. For example, the majority of the marine habitat types listed in the Annex I of the Habitats Directive are coastal habitats, whereas very few habitats in the offshore deeper areas of the Baltic Sea are included. This can be clearly seen in the result of the assessment: the deep muddy and hard clay areas remain unprotected. However, there are a lot of scientific recommendations that suggest that in order to reach ecological coherence of an MPA network, all features occurring in the area should be adequately protected. Therefore, the Habitats Directive does not currently enable the establishment of an ecologically coherent network of marine protected areas. If a truly coherent network is to be established under Natura 2000, more habitats should be included in Annexes to the Directive as well as guidelines for the establishment of larger sites.

This assessment is a first attempt to assess the ecological coherence of the Baltic Sea MPA networks. Due to its broad scale and the coarse resolution of the datasets, the results should be seen as a general overview. The use of proxies for biological communities can be used as a first approach, but in order to improve the assessment, better ecological knowledge and data is needed. We also acknowledge that several aspects were not considered in the assessment, such as quality of the habitats (e.g. water quality, oxygen depleted areas, areas of strong human impact), currents and other water movements aiding dispersal among habitat patches or life histories of species assessed. These are important considerations for future assessments. Nevertheless, this assessment already shows that there is still a lot to be improved in the current marine Natura 2000 network in the Baltic Sea.

1 INTRODUCTION

1.1 Aim of this report

The ultimate reason for all conservation work is to sustain nature under human pressure. In order to restore or maintain a functioning marine ecosystem, an array of different tools and management measures needs to be implemented, including spatial protection such as marine protected areas (MPAs). A coherent network of marine protected areas is essential for protecting valuable habitats and for supporting species that use these habitats as feeding or breeding grounds, and to make the ecosystem more resilient to external threats like eutrophication, invasive species or climate change.

Ecologically coherent networks of protected areas are required by many regional and international conventions in both marine and terrestrial areas and at the European level, by the EC Habitats Directive. As a result, initiatives to establish MPA networks have been initiated in the Baltic Sea. However, as in many other cases, the ecological coherence of the networks has not been assessed. The aim of this report is to look into the concept of ecological coherence, to present practical criteria and a first set of tools that can be used repeatedly to assess ecological coherence of the Baltic Sea MPA networks and to measure progress in the implementation of agreed international directives and conventions. We also present results of an initial assessment of the Baltic Sea MPA networks and give recommendations for further work. The assessment focuses on two main MPA networks in the Baltic Sea – primarily the EU Natura 2000 network (Habitats and Birds Directives) and secondarily the HELCOM [3] network of Baltic Sea Protected Areas (BSPAs).

[3] Helsinki Commission, the governing body of the Convention on the Protection of the Marine Environment of the Baltic Sea.

Definitions used in this report

Ecological coherence: The term ecological coherence has not been formally defined although it appears in the EC Habitats Directive (1992) and OSPAR and HELCOM declarations. In this document we follow the working definition adopted by OSPAR MASH (2006) that is based on OSPAR Biodiversity Committee's meeting document 06/3/7 and work by Laffoley et al. (2006). These criteria have also been adopted by HELCOM (HELCOM HABITAT 8 2006 b).

According to the definition, an ecologically coherent network of MPAs:

i. Interacts with and supports the wider environment

ii. Maintains the processes, functions and structures of the intended protected features across their natural range; and

iii. Functions synergistically as a whole, such that the individual protected sites benefit from each other in order to achieve the other two objectives

Additionally, an ecologically coherent network of MPA should:

iv. Be designed to be resilient to changing conditions.

Conservation feature: The populations and metapopulations of species, their habitats, the different biotopes and landscapes of the region as well as ecological processes are called features.

Marine Protected Area: There are several definitions for MPAs. The widely used definition by IUCN is: "An area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (IUCN 1988). As there are differences in the conservation targets of Natura 2000 sites, we refer to those sites always as Natura 2000 sites and, when necessary, distinguish the sites protected under the Habitats Directive (*Special Areas of Conservation, SAC*) and the Birds Directive (*Special Protection Areas, SPA*). Baltic Sea Protected Areas are similarly referred to.

MPA networks are composed of individual MPAs that are physically discrete and may have separate management structures and regimes, but that are interlinked and together meet objectives that single MPAs cannot achieve on their own (Smith et al. 2006).

1.2 International obligations to evaluate ecological coherence of MPA networks

Protected areas and their networks have been identified as key instruments to achieve the target of significantly reducing the loss of biodiversity by 2010, as agreed at the World Summit on Sustainable Development (Johannesburg 2002). According to Bennet and Wit (2001) in their IUCN document, an ecological network is regarded as "a coherent system of natural and/or seminatural landscape elements that is configured and managed with the objective of maintaining or restoring ecological functions as a means to conserve biodiversity while also providing appropriate opportunities for the sustainable use of natural resources". The target of establishing an ecologically coherent network of protected areas was incorporated into the Programme of Work on protected areas adopted by the Convention on Biological Diversity (COP7) in 2004. The overall objective of the Programme of Work is the establishment and maintenance of a global network of comprehensive, effectively managed and ecologically representative national and regional systems of protected areas by 2010 for terrestrial and by 2012 for marine areas.

At European level, there is an agreement to halt the loss of biodiversity by 2010 (Gothenburg Summit, 2001). The target of establishing marine protected areas, including representative networks by 2012, was also included in the Ministerial Declaration that was agreed upon at the fifth Ministerial Conference “Environment for Europe" in 2003 in Kiev. The Stakeholder conference held under Irish presidency in Malahide, Ireland, in June 2004 presented priority objectives and detailed targets to meet the 2010 goal. Based on the outcome of this conference, named the Message from Malahide, EU Environmental Council agreed upon Conclusions on halting the loss of biodiversity by 2010.

According to the Habitats Directive (92/43/EEC) Article 3 “A coherent European ecological network of special areas of conservation shall be set up under the title Natura 2000. This network, composed of sites hosting the natural habitat types listed in Annex I and habitats of the species listed in Annex II, shall enable the natural habitat types and the species' habitats concerned to be maintained or, where appropriate, restored at a favourable conservation status in their natural range”. In addition, Article 10 of the Directive states that “Where they consider it necessary, Member States shall endeavour to improve the ecological coherence of Natura 2000 by maintaining, and where appropriate developing, features of the landscape which are of major importance for wild fauna and flora”. According to the EU Birds Directive (79/409/EEC) Article 3, “Member States shall take the requisite measures to preserve, maintain or re-establish a sufficient diversity and area of habitats for all the species of birds [listed in the Annex I]”. These measures include, for example, creation of protected areas, re-establishment of destroyed biotopes, and creation of biotopes.

The Declaration of the Joint Ministerial meeting of HELCOM and OSPAR [4] in Bremen 2003 states that, by 2010, an ecologically coherent network of well-managed marine protected areas should be established in the Baltic Sea and the North East Atlantic. This network should include Baltic Sea Protected Areas (BSPAs) in the Baltic Sea and Marine Protected Areas in the North East Atlantic, including the Natura 2000 network. According to the Ministerial Declaration, the assessment of the ecological coherence of the network should be done in 2010 and periodically thereafter.

Coherent networks of protected areas are also required by many other international conventions e.g. the Ramsar Convention, the Convention on Migratory Species, the Bern Convention (Emerald network) and Pan-European Biological and Landscape Diversity Strategy (PEBLDS/PEEN). Legal instruments at EU-level to implement ecologically coherent networks are the Habitats Directive (92/43/EEC) and the Birds Directive (79/409/EEC).

1.3 Recent work on ecological coherence of MPAs

A joint HELCOM/OSPAR Working Programme on Marine Protected Areas was adopted in 2003 (HELCOM/OSPAR 2003). To meet the goal of assessing ecological coherence of created MPA networks in 2010, the HELCOM and OSPAR commissions have been working to develop both theoretical and more practical criteria to evaluate the networks.

[4] OSPAR Convention (combined 1972 Oslo Convention and 1974 Paris Convention) guides international cooperation on the protection of the marine environment of the North-East Atlantic.

The criteria for ecological coherence of the network of Baltic Sea Protected Areas (BSPAs) developed by HELCOM were adopted at the 8th HELCOM HABITAT meeting in May 2006 (Annex 4, HELCOM HABITAT 2006 a). These criteria were strongly based on criteria developed by OSPAR (OSPAR MASH 2006). The OSPAR commission has developed guidance to their Contracting Parties for development of an ecologically coherent network of OSPAR Marine Protected Areas (OSPAR 2005). There is ongoing work both in OSPAR and HELCOM to further develop practical criteria for assessing ecological coherence of MPAs (HELCOM HABITAT 9 2007 a, OSPAR 2007).

In the process of implementing the Pan-European Ecological Network (PEEN), the guidelines for a network of protected areas emphasize the importance of corridors enabling species dispersal. PEEN is a part of the Pan-European Biological and Landscape Diversity Strategy (PEBLDS) and it is an ambitious project in the field of ecological networks and protected areas, both on land and in the marine environment, at the scale of the whole continent.

Another effort worth mentioning in the field of MPA networks is the work conducted in the Canadian waters by Day and Roff (2000). Even though the term ecological coherence is not mentioned in their work, their criteria for a representative network of MPAs are rather similar to those identified in the initiatives presented above.

1.4 Prior criteria for a coherent network of MPAs

The criteria developed and adopted by different players reflect the specific aims of the MPA networks. The overall aims of different networks, however, are often rather similar to each other and some commonly used criteria can be identified (Day and Roff 2000, OSPAR 2005, HELCOM HABITAT 2006 a, PEBLDS/PEEN 2006). These are listed below and together they fulfil the requirements of the definition of ecological coherence mentioned above.

Adequacy. An adequate MPA has appropriate **size, shape**, **location** and **quality** to ensure the ecological viability and integrity of the populations, species and communities *for which it is selected*. Adequacy should be assessed on a site by site basis but it is a prerequisite for a coherent network. As a set, the individual MPAs should together fulfil the aims of the entire MPA network. For instance, the level of influence from the adjacent environment (e.g. anthropogenic disturbance) and location of MPAs (offshore vs. coastal) are important considerations when assessing adequacy of a site.

Representation. The full range of conservation features i.e. species, habitats, landscapes and ecological processes present within a sea area should be adequately represented within the MPA network. The network should also reflect the biogeographic variation across the sea area in question, i.e. the range of features should be adequately represented in all biogeographic regions where they occur.

Replication of features. Adequate replication of features within the MPA networks, within and across biogeographic regions, is needed to spread the risk against damaging events and long-term changes and also to ensure that the natural variation of the feature is covered (at a genetic level, within species or within habitat and landscape types). This enhances the resilience of the ecosystem (OSPAR 2005), increases representation and also adds to the number of connections between sites (enhances connectivity).

Connectivity within and between MPAs. The network should offer sufficient opportunities for the dispersal and migration of species within and between MPAs. Evaluation of connectivity is somewhat problematic as the network aims to protect a wide range of species which have ranges of dispersal and mobility that differ highly between species and at different life stages. The network should take into account different aspects of connectivity and not be focused on one element or one species to the detriment of others (OSPAR 2005). The connectivity should also take into account different stages of life history.

The overall aim of a network of MPAs is to ensure **resilience** and sustained **ecological functioning** of the ecosystem under pressure. According to IUCN (2003) "resilience is the ability of an ecosystem to recover from disturbances within a reasonable timeframe. Components of resilient MPA networks include effective management, risk spreading through inclusion of replicates and adequate representation of habitats, full protection of refugia that can serve as reliable sources of seed for replenishment, and connectivity to link these refugia with vulnerable areas within the network". Here, ecological functioning refers to interactions among species. The network should neither protect one species to the detriment of others nor allow overexploitation of one species and thereby destabilize the interactions with other species (e.g. predation, competition or mutualism). Instead, the aim should be in keeping the natural state or “balance” of the ecosystem as a whole. Resilience and ecological functioning are difficult to measure as there is no specific size, distance or other metric by which it can be described. We may come closer to achieving these targets, however, by establishing MPA networks that fulfil the criteria for ecological coherence presented above.

One important step in the process is to make these very broad, unmeasurable and theoretical criteria into practical criteria that can actually be measured and applied. Even though we are still lacking sufficient knowledge on factors that should be considered when designing MPA networks, we need to start asking questions such as what, how much, how far, how big and how many and also to consider practical implementation of the criteria. These questions are translated into measurable criteria and applied in the assessment in Chapter 4.

2 THE MARINE PROTECTED AREA NETWORKS ASSESSED IN BALANCE

The aim of the BALANCE project is to work towards implementation of international conventions and agreements (introduced in Chapter 1.5) and the aim of this work is to specifically assess the ecological coherence of the existing Baltic Sea MPA networks. The Natura 2000 network (including both the Habitats and Birds Directive sites) has been the primary focus, but the analysis has also been carried out for the network of Baltic Sea Protected Areas, BSPAs.

2.1 Natura 2000

The Natura 2000 network consists of Special Areas of Conservation (SACs), designated under the Habitats Directive and Special Protection Areas (SPAs) designated under the Birds Directive (Figure 1, Table 1). All Natura 2000 sites which have a marine component, meaning that they include a marine water area, were included in the analysis. As previously mentioned, SACs protect habitats listed in Annex I of the Habitats Directive and species listed in Annexes II and IV. According to the Directive, Member States shall take appropriate steps to avoid the deterioration of natural habitats and the habitats of species as well as disturbance of the species listed in the annexes of the directive and for which the areas have been designated. SPAs aim to protect European avian fauna, its breeding, feeding, resting and moulting areas. These areas protect bird species listed in the Annex I of the Birds Directive and prohibit actions that threaten habitats or viable populations of these species. It is important to notice that the SPA sites don't protect species other than birds and only protect underwater habitats if they are critical to bird species listed in the Birds Directive. The Natura 2000 network (both SACs and SPAs) allows human activities within the sites as long as the activities do not endanger the values the site was chosen for.

In the BALANCE project, the primary focus has been on SACs, as the Habitats Directive is designed to protect benthic habitats and the assessment of ecological coherence in BALANCE is based mainly on the benthic marine landscape and habitat maps. However, each analysis also includes a component where the SPAs have been added to the SACs. The reason for this approach is that the protection of the sites designated under the Birds Directive could be increased by designating the SPAs also as SACs. This might be easier in practice than identifying and designating entirely new sites.

Figure 1. The Baltic Sea Natura 2000 network, including SACs designated under the Habitats Directive and SPAs designated under the Birds Directive, in the study area of this assessment.

Table 1. Natura 2000 sites included in the assessment. Only sites with a marine component are included. Some of the SACs and SPAs overlap. Due to coarse resolution of the datasets, there might be inaccuracies in the figures.

	SACs		SPAs	
Country	**Number of sites**	**Marine area (Ha)**	**Number of sites**	**Marine area (Ha)**
Denmark	172	535 000	42	791 000
Estonia	31	341 000	25	642 000
Finland	130	543 000	26	141 000
Germany	44	453 000	14	498 000
Latvia	6	56 000	5	52 000
Lithuania	6	69 000	6	38 000
Poland	3	335 000	6	690 000
Sweden	266	593 000	139	362 000

2.2 Baltic Sea Protected Areas

The Baltic Sea Protected Areas (BSPA) network is based on the HELCOM Recommendation 15/5 (HELCOM 2003). The network aims to protect areas of high biodiversity, habitats of endemic, rare or threatened species and communities, habitats of migratory species, and rare, unique, or representative geological or geomorphological structures or processes. The sites have no other protection than that given by the Contracting Parties through national legislation. Many designated BSPAs overlap with Natura 2000 sites. The BSPA network consists to date (June 2007, HELCOM HABITAT 9 2007 b, Figure 2, Table 2) of a total of 78 Notified and Designated BSPAs, 14 BSPAs proposed by the contracting parties (by Rec. 15/5), and 13 sites proposed by expert consultation (Skov & Hägerhäll 1998). Management plans have been implemented for some of the 78 sites, but several sites still lack established management. The 13 sites proposed by expert consultation have not been included in this assessment.

The study area for the assessment of ecological coherence of the BSPA network was defined as the Baltic Sea region including the Baltic Sea and Kattegat, but excluding Skagerrak since that is outside the region covered by HELCOM.

Figure 2. Baltic Sea Protected Areas in the study area for the assessment. The assessment includes notified and designated BSPAs as well as BSPAs proposed by contracting parties, but not the sites proposed by expert consultation.

Table 2. *Notified and designated Baltic Sea Protected Areas in the Baltic Sea countries. (HELCOM Habitat 9, 2007a). Note that also sites proposed by Contracting Parties were included in the assessment.*

Country	Number of notified and designated sites	Total size of notified and designated (ha)	Marine area % of notified and designated sites
Denmark	16	292 500	92.2
Estonia	5	204 400	59.8
Finland	22	569 700	93.5
Germany	9	433 800	62
Latvia	4	507 000	21.6
Lithuania	3	55 700	38.5
Poland	4	67 000	40.4
Russia	2	14 500	36.8
Sweden	13	557 400	89
Total	**78**	**2 702 000**	**59.3**

Aim of the Baltic Sea MPA network

The MPA networks in the Baltic Sea, both Natura 2000 and BSPA, primarily aim to protect biodiversity. They aim to protect habitats and certain species, according to EU Habitats Directive, EU Birds Directive and HELCOM recommendations 15/5. The Baltic Sea Natura 2000 sites and BSPAs are not strict reserves but multi-use MPAs where activities that do not harm the conservation objectives can be allowed. Management of the marine resources for human use, like commercial fish populations, is thereby not the primary aim of the networks. However, fish stocks can still benefit from multi-use MPAs, if the ecosystem functions and/or the environmental conditions of their essential habitats are enhanced.

3 MARINE LANDSCAPES AND HABITATS

The assessment of ecological coherence was done on two scales: on a broad marine landscape level in the entire Baltic Sea and on a more detailed level in a pilot area, the Swedish archipelago - Åland Sea - Archipelago Sea (BALANCE pilot area 3). The broad scale analysis was based on marine landscape maps and the analysis in the pilot area was based on habitat maps, both developed in the BALANCE project (Al-Hamdani & Reker 2007, Dinesen et al. 2007, Bergström U. et al. 2007). The marine landscape and habitat maps as well as the methods used to model them are briefly presented in this chapter. For a more detailed description of the marine landscape approach, justification of chosen environmental factors and ecological relevance of the defined subcategories, see the separate BALANCE Interim report "Towards marine landscapes in the Baltic Sea eco region" (Al-Hamdani & Reker 2007). For the details of the creation of the habitat maps, see the separate BALANCE Interim reports "Mapping and modelling of marine habitats in the Baltic Sea region" (Dinesen et al. 2007) and "Fish habitat modelling in BALANCE pilot area 3" (Bergström U. et al. 2007).

3.1 Modelling marine landscapes

The marine landscape mapping carried out within the BALANCE project aims to give a trans-national overview of the marine landscapes distribution and extent in the Baltic Sea, Kattegat and Skagerrak. The classification comprises three different categorizations:

I) benthic marine landscapes, which aim to illustrate the broad scale distribution and extent of ecologically relevant entities of the seafloor, based on bottom substrate, photic depth and seafloor salinity, for example, non-photic, mud at 18-30 psu;

II) topographic bed-form features: showing the topographic layout of the sea floor, for example, "mounds", "basins" and "slopes";

III) coastal physiographic features: showing the layout of the coastal area, based on coastline characteristics, for example, "estuaries", "archipelagos" and "lagoons and lagoon-like bays".

The benthic marine landscapes aim to provide a broad-scale spatial overview of the diversity of the benthic environment in ecologically relevant entities of the seafloor. The modelling of the distribution of topographic and physiographic features on the other hand was performed with the aim to illustrate a spatial overview of the complexity and geomorphological diversity of the marine environment in the Baltic Sea.

3.1.1 Benthic marine landscapes

The benthic marine landscape map (Figure 3) provides a broad-scale spatial overview of the diversity of the benthic environment illustrating the broad-scale distribution and extent of ecologically relevant entities of the seafloor. This mapping only takes into account the geophysical and chemical characteristics of the *benthic* environment, and can therefore not be used to predict the distribution of pelagic features.

The benthic marine landscapes were mapped using bottom substrate type (5 categories), seafloor salinity (6 categories) and depth zonation (2 categories) combined in a *Raster grid overlay* analysis in ArcGIS, resulting in 60 marine landscape types altogether (Figure 3, Table 3; Table 1 in Annex 8.2). Some marine landscapes are very widely spread, while others cover only limited areas. In summary, 38 of the 60 benthic marine landscapes cover less than 1% and 11 types cover between 1-2% of the total seabed area in the region, while the remaining 11 landscape types cover the majority of the seabed. These 11 dominating landscapes are all in the deep non-photic zone of the sea. The estimated coverage of all 60 benthic marine landscapes within the study are presented in Annex 8.2.

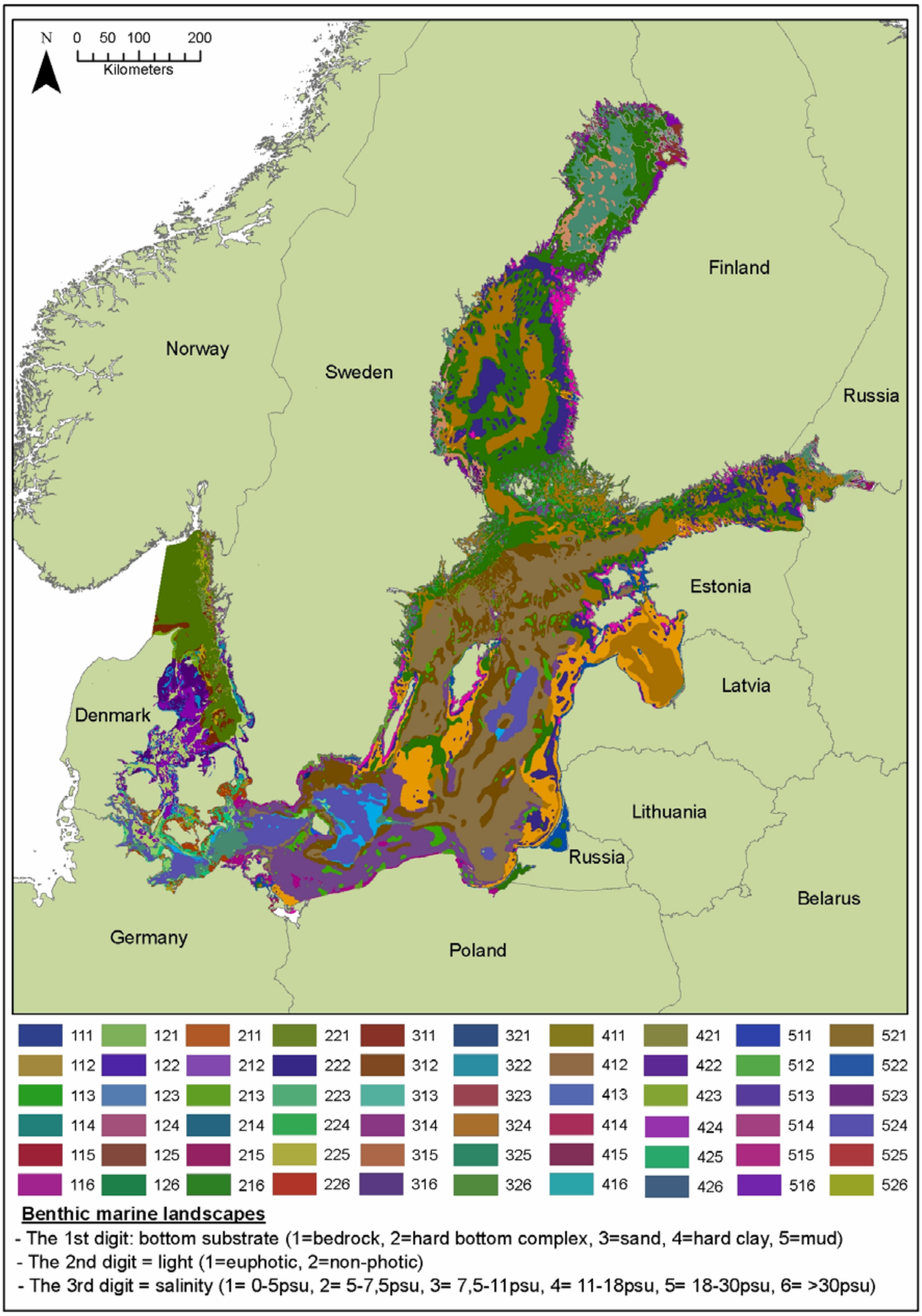


Figure 3. Benthic marine landscape map of the Baltic Sea region.

Table 3. Categories of surface sediment, seafloor salinity and depth zonation used to model benthic marine landscapes.	
Surface sediment	1) Bedrock: Hard bottom in which bedrock (crystalline and sedimentary) and bedrock covered with boulders are included. 2) Hard bottom composite that includes complex and patchy hard surface and coarse sand, boulders and sometimes also clay. 3) Sand including fine to coarse sand (with gravel exposures). 4) Hard clay sometimes/often/possibly exposed or covered with a thin layer of sand/gravel. 5) Mud including gyttja-clay to gyttja-silt.
Seafloor salinity (annual mean in modelled data,)	1) Oligohaline 0–5 psu 2) Oligohaline 5-7.5 psu 3) Mesohaline 7.5-11psu 4) Mesohaline 11-18 psu 5) Polyhaline 18-30 psu 6) Euhaline >30 psu
Depth zonation (modelled data)	1) Photic depth – euphotic zone (defined as where 1% surface irradiance touches the seafloor) 2) Below the photic depth – non-photic zone

A generalised visualisation of the estimated coverage of the marine landscape types, where the salinity categories has been combined, is presented in Figure 4. This generalisation shows that mud in the non-photic zone covers approximately 35% of the seafloor and dominates the seafloor together with hard clay in the non-photic zone (21%). Bedrock is the least common surface sediment type in both depth zones (<1% each).

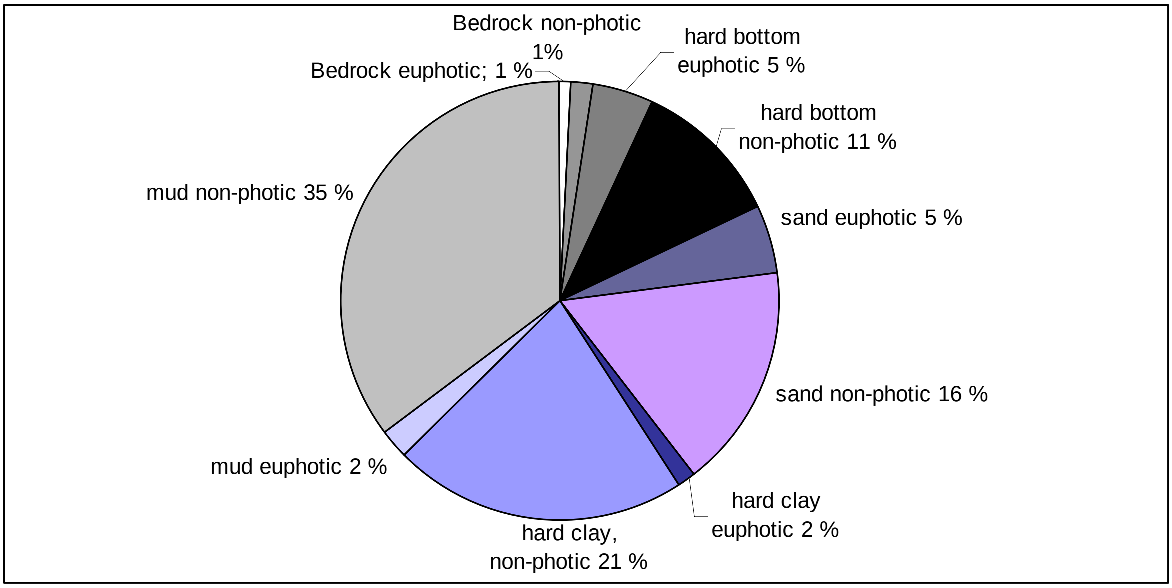


Figure 4. The estimated total coverage of the benthic marine landscape types. Salinity regime has been excluded to simplify the graph. Detailed information about all the 60 landscape types can be found in Annex 8.2.

It is important to highlight the fact that that marine ecological quality aspects, e.g. oxygen depletion of individual landscapes, were not taken into account during the mapping process. A preliminary biological validation of the categorisation was also undertaken within the context of the BALANCE project, in Kattegat (Al-Hamdani & Reker 2007) and in the Archipelago Sea area (Reijonen et al. 2007 *in prep.*). It should be emphasised that the benthic marine landscape maps are most relevant for use in a broad-scale context and not for management at a finer scale. This is partly due to scarce or low-resolution raw data in most of the offshore areas (Al-Hamdani & Reker 2007).

3.1.2 Topographic bed-form features

The dominant topographic features identified in the study area in the Baltic Sea are plains (47%), basins (22%) and clay mounds (13%) (Figures 5 and 6). Other topographic features cover relatively small total areas. Among these, troughs (1%) and bedrock mounds (2%) are the least common. These features can be used to visualize the layout of the seafloor and to gain insight into the physical complexity of the seabed in the Baltic Sea region. They should not be considered, however, as stand-alone surrogates for distribution patterns of species (Al-Hamdani & Reker 2007). Topographic features could still indicate different environments and can be used as a starting point to investigate such landscapes further. By indicating different environments they can be used, for example, to increase the probability that that the whole range of marine environments in the region is represented in the MPA network. It should be noted, that the topographic bed-form features presented in Figure 5 differ to some extent from the ones that are presented in the report by Al-Hamdani and Reker (2007). This is because an earlier version of the map was used in the assessment of ecological coherence and therefore the earlier version is presented here (Figure 5).

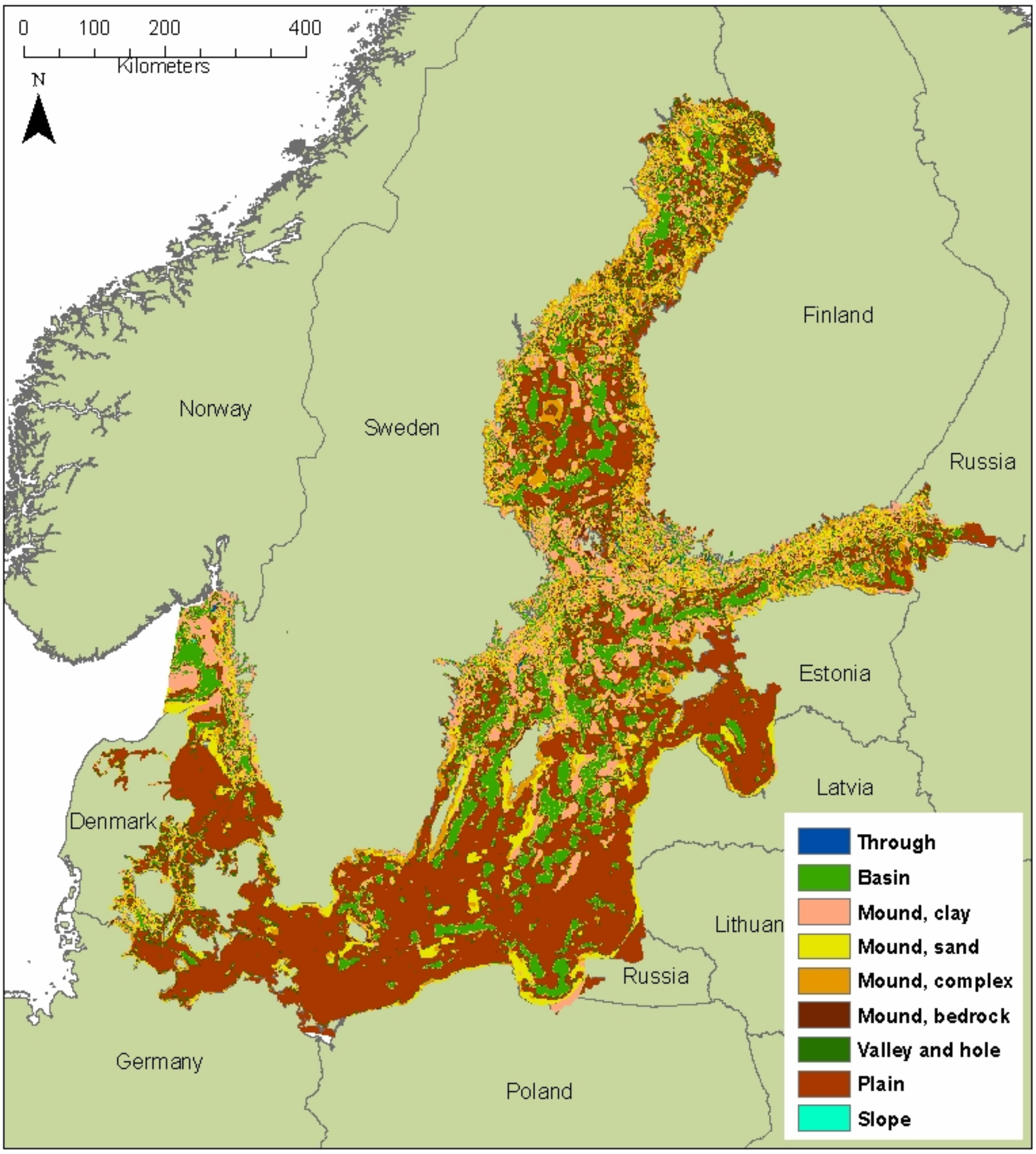


Figure 5. Topographic bed-form features of the Baltic Sea region.

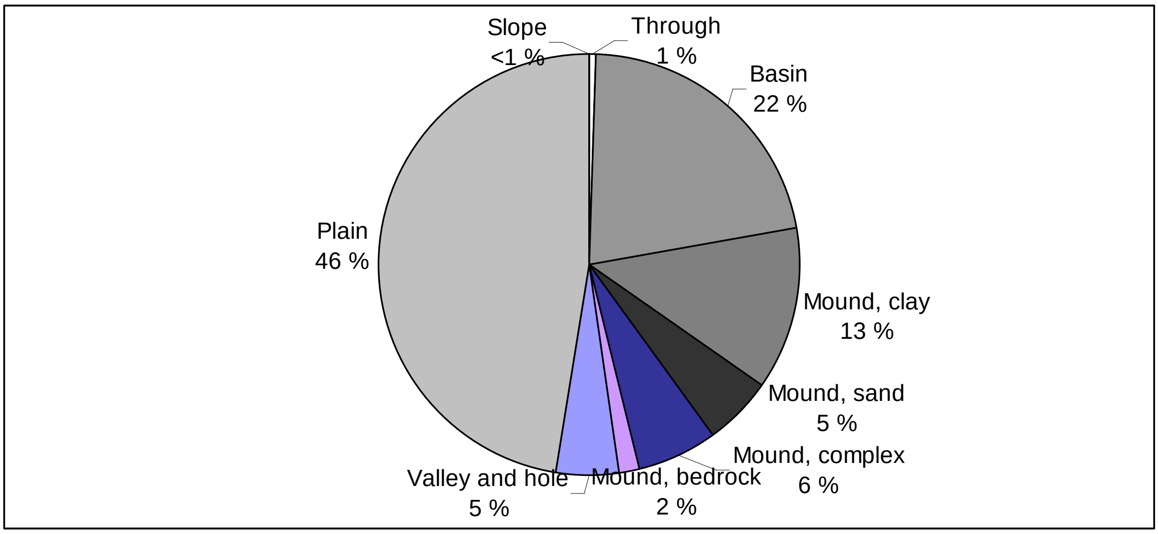


Figure 6. Estimated coverage of topographic bed-form features in the Baltic Sea region.

3.1.3 Coastal physiographic features

The coastal physiographic features can be used to characterise the transition zone from land to sea, and to illustrate the physiographic complexity of the near-shore environment (Figures 7 and 8). They should not, however, be applied as stand-alone surrogates for distribution of species assemblages (Al-Hamdani & Reker 2007). By indicating different environments they can be used, for example, to increase the probability that the whole range of marine environments in the region is represented in the MPA network. The coastal features identified in the Baltic Sea region cover about 8% of the entire region and are made up of estuaries, lagoons and lagoon-like bays, sounds, archipelagos and fjords. The majority of these features consist of archipelago and estuaries (Figure 8). It should be noted, that the features presented here differ to some extent from the ones that are presented in Al-Hamdani & Reker (2007). This is because an earlier version of the maps was used in the assessment of ecological coherence and therefore the earlier version is presented here (Figure 7).

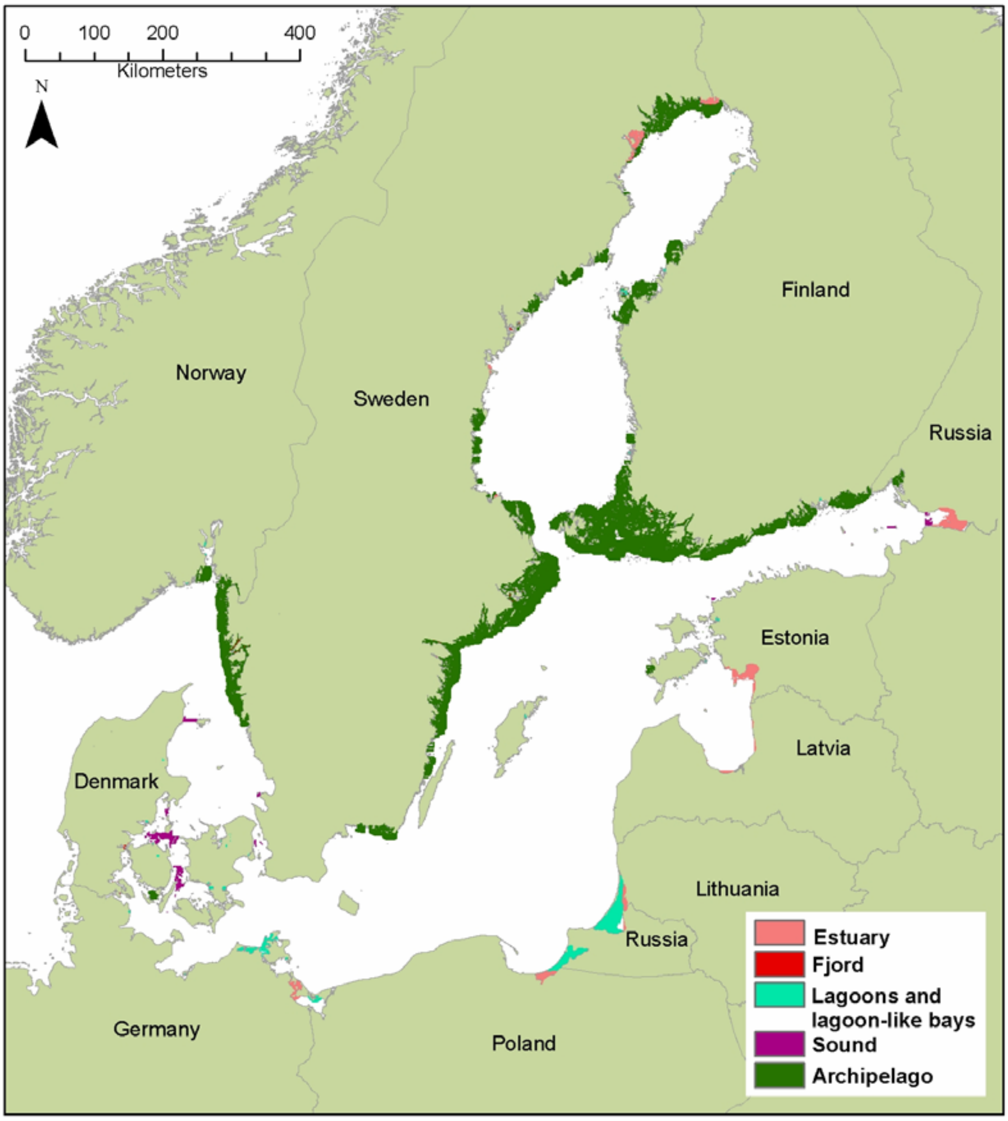


Figure 7. Coastal physiographic features of the Baltic Sea region.

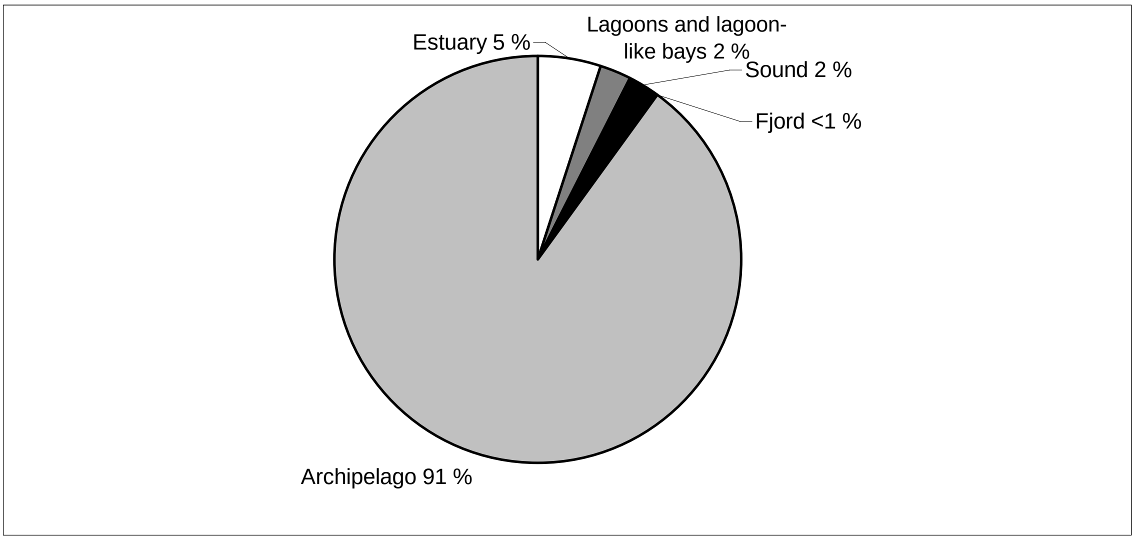


Figure 8. Proportion of each coastal physiographic feature of their total distribution in the Baltic Sea region. Coastal features cover only about 8% of the entire region.

3.1.4 BALANCE marine landscapes and Natura 2000 habitats

Some of the topographic bed-form and coastal physiographic features identified in BALANCE coincide to some extent with the Natura 2000 habitats (the Habitats Directive Annex I). The Natura 2000 habitats and the marine landscape features are not defined at the same scale and the same classification criteria have not been used. The identified topographic and bed-form features and coastal physiographic features are therefore not directly comparable with Natura 2000 habitats, even if they share the same names. In order to clarify the association between them, a comparison was made between the two classifications by comparing the definitions of the Natura 2000 habitats in the "Interpretation Manual of European Union Habitats" (EC 2003) and the classification used in BALANCE to define the topographic bed-form and coastal physiographic features (Al-Hamdani & Reker 2007). The comparison is presented in Annex 8.1. In summary, it can be concluded that there is a high probability of finding *Sandbanks* (1110) within the topographic bed-form feature *sandy mound*. In the *bedrock mounds* there is a high probability of finding *Reefs* (1170) and in the coastal physiographic feature *estuaries* the corresponding Natura habitat *Estuaries* (1130) most likely occur. *Coastal lagoons* (1150) may be found within *lagoons and lagoon-like bays* and *Boreal Baltic Narrow inlets* (1650) may occur within *fjords*.

In most Baltic Sea countries the national interpretations of the definitions of Natura 2000 habitats also list typical species for these habitats, whereas the topographic and coastal physiographic features were identified by modelling of geophysical data only. The features, however, can indicate potential sites for the Natura 2000 habitats and the representation assessment can therefore be used as a coarse indication of the level of protection of the Natura 2000 habitats.

3.2 Modelling habitats

3.2.1 Natura 2000 Habitats

Maps of the spatial distribution of species and habitats were produced by spatial modelling and GIS analysis in four BALANCE pilot areas. The modelling exercises are further presented in Dinesen et al. (2007) and in Bergström U. et al. (2007), but here we give a short overview of the modelling work carried out in BALANCE pilot area 3, the Swedish archipelago - Åland Sea - Archipelago Sea area, as these maps were used as background data in the assessment of ecological coherence of the marine Natura 2000 network in this pilot area.

Maps of the spatial distribution of the EU Habitat Directive Annex I habitats 1) 1110 Sublittoral sandbanks, 2) 1130 Estuaries, 3) 1150 Coastal lagoons, 4) 1160 Large shallow inlets and bays, 5) 1170 Reefs, 6) 1610 Baltic esker islands and 7) 1620 Boreal Baltic islets and small islands were produced using GIS tools. The maps should be comparable over the nation border between Sweden and Finland.

The selection criteria for each habitat type were derived from the Interpretation manual of European Union Habitats (EC 1999) and the national, Finnish and Swedish descriptions of the habitats. No actual datasets that outline the habitats were available. Datasets used to derive the habitat maps included different shoreline datasets, river flow data, elevation curves and models, land use, water depth, bottom substrate, soil type on islands and on mainland, wave exposure, secchi depth, coastal exploitation data, satellite data and aerial photos. The GISanalyses used were different for each habitat and for some habitats the analyses were also different between the two countries (see Dinesen et al. 2007 for details).

3.2.2 Essential fish habitats

Maps of essential fish habitats were produced by spatial predictive modelling. The models were based on empirical observations on the relationship between a species occurrence and relevant environmental variables e.g. depth, wave exposure and turbidity. Individual species and life stages were studied separately.

The species-environment relationships can be fitted by different techniques. In this study, a multiple regression analysis based on Generalized Additive Models (GAM) was used. The statistical relationships were then used to make spatial predictions, which show the probability of occurrence of the species/life-stage studied, in a GIS map covering the whole target area. The probability maps were subsequently reclassified into dichotomized maps of suitable and unsuitable habitat, using the True Skill Statistic for determining the probability threshold (Allouche et al. 2006).

The largest bottleneck for application of the modelling approach was the availability of geographical data on relevant environmental variables. The following data were used in the modelling: 1) Georeferenced abundance data of the fish species and life stages studied (point data) from Sweden, Åland and Finland. 2) A set of relevant environmental variable maps, depending on the ecology of the fish species/life stage to be modelled (full coverage data). The variables depth, wave exposure, and turbidity were included. A critical point for the analysis was to achieve environmental variable maps with adequate extent, resolution and precision.

Map predictions were constructed for spawning habitats of perch, and nursery habitats for perch, pike, roach and pikeperch. More details on the models can be found in BALANCE Interim Report No 11 " Fish habitat modelling in BALANCE pilot area 3" (Bergström U. et al. 2007)

4 ASSESSMENT OF THE BALTIC SEA MPA NETWORKS

This chapter describes the initial assessment of the Baltic Sea MPA networks carried out within the BALANCE project. The criteria used in the assessment were developed based on a review of scientific literature and the outcome of two workshops: a joint *BALANCE / HELCOM workshop on ecologically coherent networks of MPAs in the Baltic Sea and North East Atlantic* (Helsinki, October 2006) and a *BALANCE workshop on ecological coherence and representativness of networks of Marine Protected Areas* (Helsinki, March 2007).

The following criteria were applied in the assessment: **adequacy** (in terms of MPA size only), **representation, replication** and **connectivity** (of marine landscapes and habitats). These four broad and theoretical criteria, described in Chapter 1.4 and that have been agreed by e.g. HELCOM and OSPAR, were further developed into more practical criteria that can be measured and used in practice. In the beginning of each of sub-chapter, the scientific basis for using these criteria is presented, as well as the more detailed criteria and measures used in the assessment.

4.1 Preparation of data sets and delineation of the study areas

All data preparation and analysis was done using ArcGIS 9 and all layers were in projection UTM-34N. The data only allowed the analysis to be completed on a coarse scale. This should be kept in mind when interpreting the results.

Study Area

The study area for the Natura 2000 assessment was defined as the Baltic Sea region including the Baltic Sea, Kattegat and Skagerrak. The waters of non-EU countries (Russia and Norway) were excluded from the analysis. The study area was slightly different for the BSPA network assessment including the Baltic Sea (with Russian waters) and Kattegat, but excluding Skagerrak since it is outside the region covered by HELCOM (see Figures 9 and 10).

The marine area was delineated by a coastline with an approximate resolution of 1:250 000 (”Europe Countries” dataset published in ”ESRI Data & Maps”). The only addition made to this coastline was that of the major fjords in Denmark. The polygon was further split into exclusive economic zones (EEZ) and territorial waters (TW). Estimate polyline data from HELCOM was used to split the region into EEZ and TW. It should be noted that the polyline data defining the EEZ and TW are estimations of the actual zones. These divisions were made merely to enable statistics by country and coastal vs. offshore areas (Figure 9).

The polygon was also split into six sub-regions; the Baltic Proper, the Bothnian Bay, the Bothnian Sea, the Gulf of Finland, Kattegat and Skagerrak. A data set from HELCOM defining the 18 sub-regions in the HELCOM marine area, the Baltic Sea and Kattegat was used to form five regions (the Baltic Proper, the Bothnian Bay, the Bothnian Sea, the Gulf of Finland, and Kattegat). The 18 sub-regions were merged to form five regions in line with the major thresholds causing the major shifts in salinity regime. Skagerrak is outside the HELCOM marine area (Figure 10).

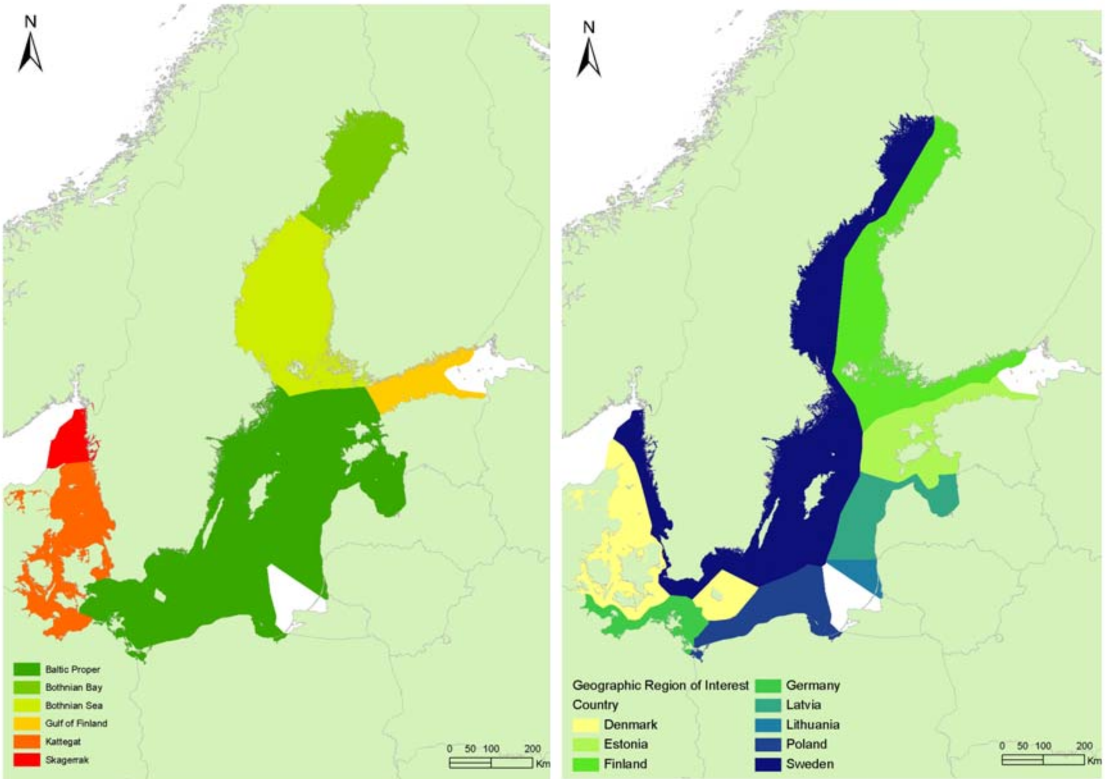


Figure 9. Assessment of the Natura 2000 network. Division of the study area into sub-regions and countries.

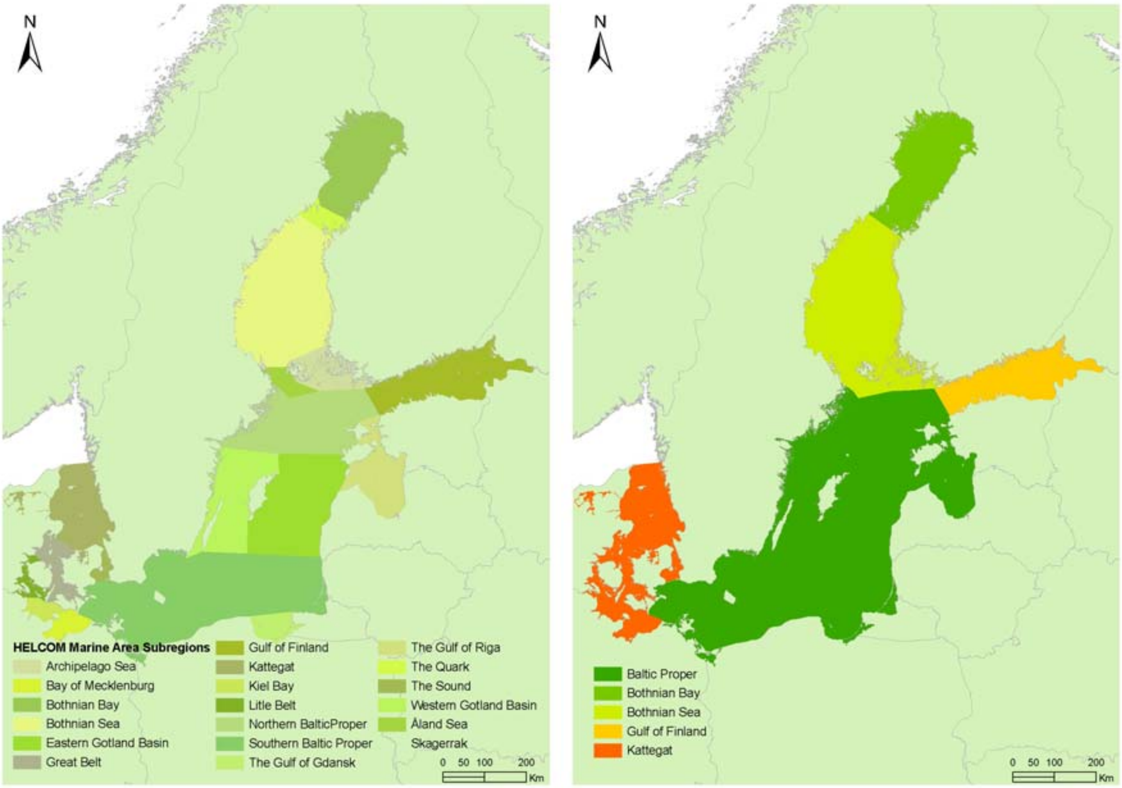


Figure 10. Assessment of the BSPA network. Division of the Baltic Sea into the 18 HELCOM marine area sub-regions and to the 5 larger sub-regions used in the BALANCE project. The division into countries was made in the same way as for the Natura 2000 network.

Marine Protected Areas

Designated Natura 2000 sites, SACs and SPAs, were compiled from national data bases (see Chapter 7) and merged to form two uniform GIS layers, representing SACs and SPAs, respectively. The two mask layers were also merged to form a third layer representing the total coverage of all Natura 2000 sites (both SACs and SPAs).

Designated Baltic Sea Protected Areas (BSPA) in the categories "designated and notified" and "proposed by contracting parties" from the HELCOM BSPA-database (http://bspa.helcom.fi) were used to form a separate layer.

The study area polygons were used to separate the marine area from the terrestrial area. The resolution of the coastline layer was lower than the site layers. Smaller coastal sites with marine area may therefore have been excluded, or included with underestimated area. For the same reason, several very small islands may have been identified as marine area. The problem was at its extreme in the Finnish Archipelago Sea, where thousands of small islands were identified as marine area. Since many of these small islands are designated as Natura 2000 sites, inclusion of them in the assessment would have caused errors in the analysis, e.g. severe overestimation of small marine sites in the adequacy analysis and errors in the replication and connectivity analyses. In order to minimize the error, the small island sites in the Finnish waters that according to more detailed data layers had no marine component were deleted from both of the datasets (SACs only and SACs and SPAs combined). This was done by comparing the datasets to a 1:20 000 coastline dataset and deleting the island sites that matched the coastline.

Since the adequacy analysis had the aim of assessing the size of the separate patches of the protected areas, and not the size of sites (one site may consist of several patches), it was necessary to perform some further operations on the Natura 2000 sites data before assessing adequacy. At first, all of the SACs were dissolved in order to create one multi-part polygon. After this, the polygon was divided into single part patches. This way all patches sharing a common boundary were dissolved to form one patch and all unconnected patches belonging to the same site were separated. The same process was repeated for the layer with SACs and SPAs combined.

Benthic Marine Landscapes

The benthic marine landscapes (200 × 200m grid) were mapped using bottom substrate type, seafloor salinity and depth zonation combined in a *raster grid overlay* analysis in ArcGIS (refer to Chapter 3.1.1). It was obvious that the smallest landscape patches (down to 4 hectares) were probably artefacts related to the creation of the map and not true marine landscapes. It was therefore necessary to decide a minimum size for a patch that should be considered a replicate of a marine landscape type.

It was decided that landscape patches smaller than 24 hectares (6 pixels) should not be considered replicates of a particular landscape. This decision was based on the resolution of the datasets that were used to create the landscape maps. The small patches were dissolved into larger patches in their surroundings.

This generalized dataset was used for the assessment of replication and connectivity of the benthic marine landscapes within the Baltic Sea MPA networks.

4.2 Assessment of adequacy

In order to be adequate, an MPA needs to have sufficient size, shape, location and quality to ensure the viability of the feature/features for which it was selected. Adequacy is a criterion that ideally needs to be assessed on a site by site basis.

Size

A long scientific debate has focused on the question should a network of MPAs consist of "single large or several small" (SLOSS) or, alternatively, "a few large or many small" (FLOMS). Large MPAs support many habitats, have large populations of organisms, and reduce border effects (Airamé et al. 2003, Fernandes et al. 2005). On the other hand, from the perspective of metapopulation theory, many interconnected MPAs support more persistent populations than a single or few large (e.g. Zhou & Wang 2006), if the total area is the same.

The size of an individual MPA should first of all be determined by the purpose of the site. For an individual site, which aims purely to protect biodiversity, it is probably better the larger the site is. The size is not a target in itself but the biodiversity it can support. In reality, however, there are often other interests and therefore limitations to the overall area protected in an MPA network and to the possible size of an individual MPA, it has to be a balance between size and number. The overall rule is that the MPA should be large enough to support the feature or features for which it is selected. When protecting biodiversity, size requirements of a site can vary considerably depending on the feature. For example, according to McNeill & Fairweather (1993), several small MPAs should be preferred if seagrass beds are of special concern. For many invertebrate species and seaweeds, small reserve sizes can be planned, as the intended species does not migrate outside the boundaries frequently (Saldek, Nowlis & Friedlander 2005). Also from the fisheries enhancement perspective, some scientists prefer many small or medium-sized reserves rather than few large (Roberts et al. 2001, 2003). The large edge-to-area ratios of small reserves result in higher rates of juvenile and adult spill-over (Attwood & Bennett 1995). This is important for meeting both fishery and conservation objectives (Roberts et al. 2003). An empirical study in a network of five small marine reserves in St. Lucia showed that, within five years of creation, adjacent catches of artisanal fishers outside the sites increased by 46-90%, depending upon the type of gear the fishers used (Roberts et al. 2001). Small MPAs, however, will only function if there are essential linkages (connectivity) between sites and features. If a habitat or a landscape is rare in the area, this is most likely not the case. Larger areas will probably be needed to protect rare and fragmented habitats. Small areas are also vulnerable as some species may easily live in a larger area than the MPA and thus be exposed to exploitation (Roberts et al. 2003).

In a network of MPAs, **variation** in MPA size is also important (Roberts et al. 2003). In a few very large reserves, almost pristine ecosystems can be retained, while many small and medium-sized reserves suit many species, spread out risks and help capture ecosystem heterogeneity. Also **location** (e.g. coastal vs. offshore) has implications for the size of an MPA. Generally, the near shore areas are dominated by finer scale benthic processes and the offshore areas that are dominated by coarser scale pelagic processes. Therefore the pelagic features should generally be protected with larger sites (OSPAR MASH 2006).

Is there a minimum size for an MPA?

Shanks et al. (2003) found that some propagules (i.e. a seed, spore or other product of reproduction) had a bimodal dispersal in water: those who dispersed <1km and those who dispersed >20km. The former ones stayed in the water <100h and the latter ones >300h. They think that mid-distance dispersal is an unstable evolutionary strategy. This has an effect on MPA planning: the area should be large enough to hold the short-distance propagules (2km in diameter, but 4-6km is safer) and close enough to each other to receive long-distance propagules (20km is close enough for the long-distance propagules). Also Curley et al. (2002) suggest that a minimum MPA size should be 2-6km in diameter (c. 300-3000ha) or should comprise a network of small areas with similar habitats. Parnell et al. (2005) reported that a reserve of c. 200ha was probably too small as it did not enhance the populations outside the reserve. HELCOM recommends a minimum MPA size of 3000ha for its BSPA network (HELCOM 2003).

Shape

Not only size but also shape affects an MPA. If practical, the circular shape has the least edge-to-area ratio and therefore the edge-effects are minimal. In multiform or elongate sites, the edge-effect increases. Compactness, as suggested by OSPAR MASH (2006), numerates MPA shape by the equation $C = (4\pi A/p^2)^{0.5}$. In this equation, C is the compactness, A is an area of the site, and p is its perimeter. This is based on Selkirk's (1982) *circularity ratio*,[5] where a circle receives a score of 1; i.e. it is the most compact shape, and all others will have a score less than that. In a small site where edge-effects can be considerable, compactness of the site is most likely advantageous. In larger sites, however, compactness might be less important and less compactness might even be preferred to allow spill-over to adjacent areas. For management reasons, MPAs with simple/straight boundaries are easier/preferable.

Quality

In contrast to terrestrial threats, where physical habitat degradation is of the primary concern, the Baltic environment faces decreased water quality, in terms of increased water turbidity, chemical pollution, and nutrient concentrations (Kautsky et al. 1986, Karlson et al. 2002, Rönnberg & Bonsdorff 2004, Lehtonen & Schiedek 2006). Increased eutrophication has caused anoxic deep water layers, covering vast areas of the Baltic Sea[6]. The anoxic water prevents marine life and while the recolonization of some species is relatively fast, the benthic community recovers slowly (Gray et al. 2002, Karlsson et al. 2002). =Habitat loss due to underwater construction, excavations and dredging and general disturbance by e.g. noise also affect the underwater environment (Rönnberg, 1981, Frankel & Clark 1994, Koschinski et al. 2003 and references therein, Eriksson et al. 2004, Perus & Bonsdorff 2004, Roos et al. 2004).

The quality issues are of major importance when selecting sites for a network of MPAs. They should also be considered when assessing the adequacy of existing sites. For example, a site that has been severely affected by eutrophication or is otherwise disturbed may not contribute to the coherence of a network to the same extent as sites in more pristine areas, if the quality is not improved.

Adequacy criteria applied

Marine landscape scale[7]:

The assessment of adequacy should ideally be done on a site by site basis, by looking at the purpose of the protected area and by evaluating it's suitability for its purpose in terms of size, shape and quality (e.g. water quality, distance from the sources of disturbance). At the marine landscape scale, however, with several hundreds of sites, this kind of approach was impossible. In this assessment the adequacy of the sites was conducted simply by looking at the **size distribution** of the Natura 2000 sites and BSPAs in the whole Baltic Sea, in the inshore vs. offshore areas and in each Member State. No specific number for adequate minimum size was set, but a bias in the size distribution, a lack of a certain size category or bias in size distribution between near shore and offshore waters may indicate a possible gap in adequacy.

The **shape** of the MPAs and their **quality** (in terms of water quality or potential threats) were not considered in this assessment.

5 The square root is not in Selkirk's original formula. Its addition allows for the linear comparison of scores between sites. For example, if $C_1/C_2 = 2$, then it can be said that Site 1 is twice as compact as Site 2, in that it has half as much edge per given hectare.

6 HELCOM State of the Baltic Sea environment. http://helcom.navigo.fi/environment/indicators2003/Oxygen/en_GB/hydro/

7 Habitat scale criteria are presented in Chapter 5.

4.2.1 Methodology

The areas for all Natura 2000 and BSPA sites were calculated. The size distribution of sites was assessed for the whole Baltic Sea, for the territorial waters and EEZ separately and separately for each Member State.

4.2.2 Results and discussion on the Natura 2000 network assessment

The size distribution of Natura 2000 sites shows that the Baltic Sea region is dominated by small sites, <1000ha (Figure 11). Only 13% of all SACs fulfil the minimum guideline of the 3000ha size set by HELCOM (2003) and scientists (e.g. Curley et al. 2002, Shanks et al. 2003). Compared to the absolute minimum size of 300ha mentioned in the literature and based on dispersal distance of short-distance dispersers (Shanks et al. 2003), still only 36% of the SACs can be called adequate. Adding the SPAs to SACs in the assessment increased the number of sites in most size classes and particularly in the largest size class (>100 000ha). Designating SPAs as SACs, however, would increase adequacy of the Natura 2000 network only slightly in terms of size.

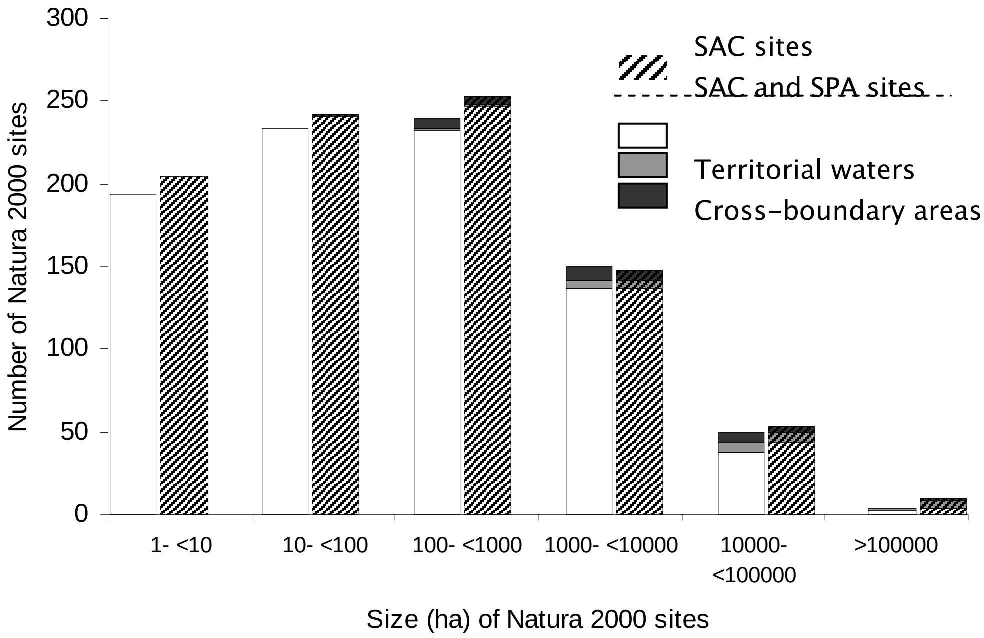


Figure 11. Size distribution of Natura 2000 sites: SACs only and SACs and SPAs combined. The sizes are shown separately for sites in territorial waters, in exclusive economic zones (EEZ) and for sites that reach over the EEZ boundary (cross-boundary areas). Note that the amount of coverage of SPAs alone cannot be read out of the graph since there is overlap in areas between the two networks.

As shown by the representation analysis (Chapter 4.3), the majority of the Natura 2000 sites are situated in the territorial waters with only a few crossing the border of the EEZ or being solely in the EEZ. Over 36% of the sites in the EEZ are larger than the 3000ha guideline (56% if areas crossing the EEZ boundary are included). There are only a couple of sites belonging to the smallest size classes in the EEZ.

At this stage, it can be concluded that, based on size of the sites, the adequacy of the Natura 2000 network is not sufficient. More large sites are needed, both in the territorial waters and in the EEZ.

The size distribution of Natura 2000 sites in different EU-Member States is presented in Figure 9 in Annex 8.3. In summary, the size distribution of SACs in Denmark and Germany are rather well balanced between small and large sites, whereas in other Member States there are too few large sites, gaps in some other size categories, or the number of sites is too small to draw any conclusions.

Adequacy results in summary (Natura 2000):

1. The Natura 2000 network is not adequate in terms of size of the sites as the sites are strongly biased towards small sites. Most sites are smaller than 3000 hectares, which is a minimum guideline given by HELCOM and many scientists.
2. Other important aspects of adequacy such as quality or shape of the sites were not considered in this assessment

4.2.3 Results and discussion on the BSPA network assessment

Generally, the BSPA sites are much larger than the Natura 2000 sites (Figure 12). The majority of the sites belong to the size classes over 10 000 hectares and even 77% of the sites are larger than recommended 3000ha. As with the Natura 2000 sites, most of the sites are situated in the territorial waters and only a handful extends into the exclusive economic zone (EEZ): Nine sites extend into the EEZ and six more sites are solely in the EEZ. The latter ones belong to the largest size categories. Although there are other gaps in the ecological coherence of the BSPA network, it can be considered relatively sufficient on the basis of the size distribution among existing sites. This should be maintained when new sites are added to the network. It is also important to remember that a number of the BSPAs included in the analysis are not designated (only proposed) and still do not have legal protection.

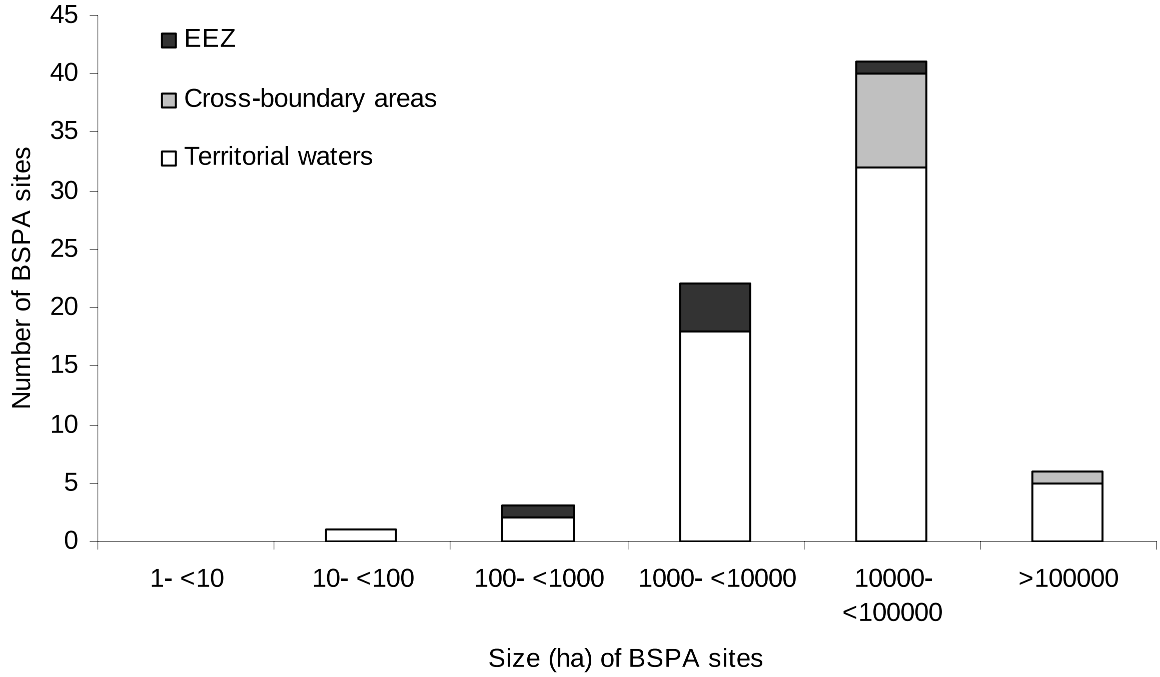


Figure 12. Size distribution of BSPA sites in territorial waters and in exclusive economic zones (EEZ) of the Baltic Sea. The sites that cross the border of EEZ are presented as cross-boundary areas.

Adequacy results in summary (BSPA):

1. The BSPA network can be considered adequate in terms of sizes of the sites, as the majority of the sites are 10 000-100 000 hectares in size. This should be maintained when new sites are added to the network. HELCOM recommends a minimum MPA size of 3000 hectares for BSPAs.

2. It is important to keep in mind that a number of the BSPAs included in the analysis are not designated (only proposed) and still do not have legal protection.

3. Important aspects of adequacy, such as the shape and the quality of the sites was not assessed.

4.3 *Assessment of representation*

Representation in its simplest form means "protecting some of everything" i.e. ensuring that all marine landscapes, habitats, species and ecological functions present in a region are adequately protected (Groves et al. 2002). Representation of all biogeographic regions is a prerequisite for protection of biodiversity (Airamé et al. 2003, Roberts et al. 2003). E.g. Day and Roff (2000) have argued that representation of different biogeographic regions in a network of MPAs should be a core conservation objective, because the species assemblages will be distinct in each.

Once the representation of all biogeographic regions is ensured, it is essential that the full range of species, habitats, marine landscapes, ecological processes and environmental gradients (e.g. depth and wave exposure) within these regions is adequately protected

(Chiappone et al. 2000, Day & Roff 2000, Airamé et al. 2003, Roberts et al. 2003). It has been suggested that the minimum total area set aside for the protection of each habitat should be approximately related to its relative prevalence in the region, which means that a similar percentage of each feature is protected in the region. Some features could, however, need more protection than others. It has for example been suggested that special care should be taken to guarantee inclusion of rare as well as sensitive and threatened habitats and species (Roberts et al. 2003). Bottleneck areas, such as spawning areas or narrow straits, have specific need for protection (Roberts & Sargants 2002). Isolated and regionally rare habitats and species may need a larger fraction protected than regionally extensive and widespread habitats (Roberts & Mason, unpublished). This is because they have little connection to populations in other protected areas and must rely on self-replenishment. Some habitats, like places under severe threat and with long recovery times, may require full protection (Roberts & Mason, unpublished).

Representation can also be seen as an insurance in situations with lack of knowledge about the exact distribution of species and habitats. By protecting a representative and accurate share of the broad scale features in a marine area, unknown biodiversity (species and habitats) will most probably also be covered.

It is widely acknowledged that habitat heterogeneity is of primary importance in a successful MPA network (Chiappone et al. 2000, Roberts et al. 2003). Recent studies have also underlined the importance of life history in MPA design. Invertebrates and, particularly, fish species use different habitats at different life stages (Ruzycki & Wurtsbaugh 1999, Beck et al. 2001, Hiddink 2003, Mumby et al. 2004, Lipcius et al. 2005). Therefore, all these habitats need to be sufficiently covered. In addition, the migratory corridors between them should be ensured or protected.

How much is adequate representation?

How much is then adequate protection for a species, a habitat or a marine landscape? There is very little advice in scientific literature about how much of a certain region, landscape or habitat should be protected to adequately ensure its long-term viability. It also depends on the aim of protection e.g. if it is for biodiversity conservation or fisheries management, or both. Some examples exist, however, in both scientific and grey literature. In a review of over 30 studies addressing the question of how much **of a sea area** should be protected, Roberts & Hawkins (2000) found that the estimates ranged from 10% to 80% of the sea area in a region. The majority of these 30 studies were from the fisheries perspective, seeking to find how much of a sea area should be protected to maximize catches. The answer varied depending on the characteristics (e.g. mobility or vulnerability to fishing) of the species considered. In the case of highly migrating species, such as cod, the network should include 80% of the fishing grounds (Lipcius et al. 2005). Taken across a wide range of species, theoretical work indicates that reserves covering between 20 and 50% of the sea area will maximize catches (Roberts & Mason, unpublished). Some of the studies included in the summary by Roberts & Hawkins (2000), however, also looked at the question from other perspectives than fisheries, e.g. how much of a sea area would need to be protected in order to create a network of MPAs for protection of biodiversity, that includes replicates and represents all habitats in all biogeographic regions in sites of sufficient size. Answers typically ranged from 15-30%.

If instead considering how much **of a habitat** should be protected, the scientific recommendations suggest that 30-50% (Airamé et al. 2003) or 20-50% (Saldek Nowlis & Friedlander 2005) of each habitat should be protected to ensure viability of populations.

Even if solid scientific proof about how much of different habitats and/or species should be protected to ensure long-term viability is lacking, there are guidelines that have been followed in other parts of the world. The U.S. National Research Council supports the idea that 20% of each habitat needs to be protected in order to provide at least some degree of support for fisheries and biodiversity (NRC 2001). Also the World Parks Congress in Durban 2003 recommended that "marine protected area networks should be extensive and include strictly protected areas that amount to at least 20-30% of each habitat" (IUCN 2003). When evaluating the countries' contribution to the Natura 2000 network, the European Commission uses 20% and 60% (for priority habitats) of each habitat type as a guiding principle for sufficient protection. Australia has already taken action to attain a high level of protection: in the Great Barrier Reef zoning plan the target was to have a minimum 20% of each "bioregion" protected (Great Barrier Reef Marine Park Authority 2005). The network of no-take marine protected areas in the GBR now contains at least 20% of all described bioregions and includes 33% of the GBR Marine Park overall (Fernandes et al. 2005).

More information on representation and proposed criteria for selection of a representative network of MPAs in the Baltic Sea has been compiled in the BALANCE Interim report No. X (Liman et al. 2007).

In summary, many marine studies and international conventions have suggested that ecologically functional networks of marine protected areas need to cover *at least* 20 percent of each habitat in a region, if the biodiversity of that region is to be fully conserved (Roberts & Hawkins 2000, Airamé et al. 2003, IUCN 2003, Fernandes et al. 2005, Great Barrier Reef Marine Park Authority 2005, Saldek Nowlis & Friedlander 2005), but that regionally rare, sensitive and threatened habitats and species may need a larger proportion protected than ,for example, regionally extensive and widespread habitats (Roberts & Mason, unpublished).

Representation criteria applied

Marine landscape scale:
In this analysis we have aimed towards consistency with the scientific recommendations and political targets presented above. Therefore, a minimum of 20% protection of each benthic marine landscape type has been used as a guiding principle upon which the designated sites were assessed. The following categories were used to classify the results: <10% protection for bad representation, 10-20% for poor, 20-30% for moderate, 30-60% for good, and >60% for high.

4.3.1 Methodology

Geographical representation
The proportion of each country's marine area designated as SACs and SPAs was estimated using an overlay analysis in ArcGIS. A differentiation between areas designated within territorial waters and in the exclusive economic zone (outside territorial waters) was made to give an estimation of how well the directives have been implemented in near shore and offshore areas in each country as well as in the entire region.

The coverage and distribution of designated sites between six major salinity sub-regions (Baltic Proper, Bothnian Bay, Bothnian Sea, Gulf of Finland, Kattegat and Skagerrak) were also estimated and used as a proxy for how well the current sites represent the different biogeographic regions in the Baltic Sea.

A corresponding analysis on the coverage and geographical distribution of sites over sub-regions and countries was also carried out on the BSPA network.

Marine landscape representation
The quantity of each marine landscape type within the designated SACs as well as within designated SACs and SPAs together were also estimated using an overlay analysis in ArcGIS. The representation of the three marine landscape characterizations, benthic marine landscapes, topographic bed-form features, and coastal physiographic features, were assessed separately. Note that the benthic marine landscapes in the Danish area Limfjorden were not mapped and hence the Natura 2000 sites in this area could not be taken into account. The proportionate representation of landscapes were categorized according to five levels; bad <10%, poor 10-20%, moderate 20-30%, good 30-60 % and high 60-100%.

The BSPAs were only assessed with respect to the benthic marine landscape types.

4.3.2 Results and discussion on the Natura 2000 network assessment

Geographical distribution
Approximately 7% of the Baltic Sea (including Kattegat and Skagerrak) are designated as SACs under the Habitats Directive, representing approximately 11% of the territorial waters and 3% of the exclusive economic zone, EEZ.

The proportion of the marine area designated as SACs differs considerably between different sub-regions (Table 4). The lowest proportion of designated sites is seen in the northern low-salinity areas in the Bothnian Sea (2%) and in the Bothnian Bay (5%). In comparison, Kattegat and the Gulf of Finland, both with 15% representation, are relatively close to the minimum recommended level of 20%. The network of SACs, however, does not cover 20% of the area in any of the sub-regions (Table 4).

Table 4. The coverage (%) of Natura 2000 SAC sites in the sub-regions of the Baltic Sea.	
Sub-region	**Coverage (%)**
Bothnian Bay	5
Bothnian Sea	2
Gulf of Finland	15
Baltic Proper	6
Kattegat	15
Skagerrak	7

The proportionate coverage of SACs also differs considerably between the EU-Member States. Germany has designated a large proportion (30%) of its total water area, compared to most of the other Member States. Sweden and Latvia have both designated less than 5%, 4% and 2% respectively (Figure 13).

The territorial waters are generally better represented than areas further offshore (Figure 13). The same trend, a higher proportion of designation in territorial waters than in the EEZ, is seen throughout all the EU-Member States, except in Germany where the proportionate distribution is more or less equal and where more than 30% of the EEZ has been designated. Finland, Estonia, Latvia, Lithuania, Sweden and Denmark have none or very limited coverage of designated sites in their EEZ.

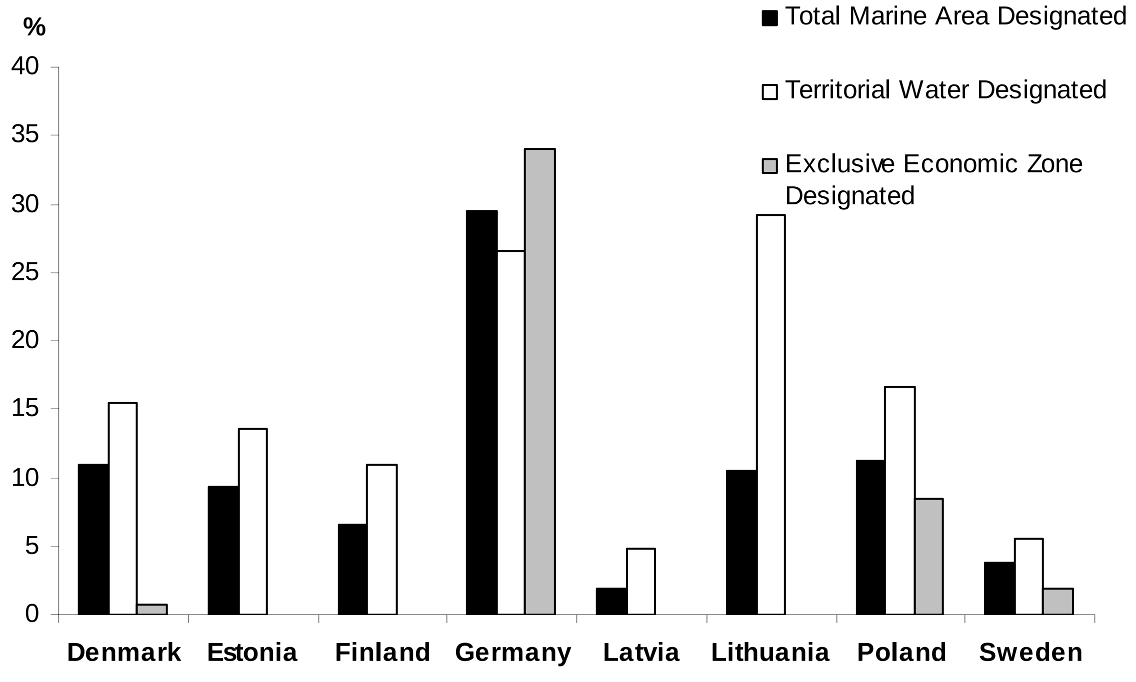


Figure 13. The percent coverage of SACs of the total marine area (black), territorial waters (white) and exclusive economic zone (EEZ, grey) in each country.

If the SPAs are included in the analysis, the coverage of Natura 2000 sites increases from 11% to approximately 16% of the territorial waters and from 3 to 4% of the EEZ of the EU-Member States. SPAs have a higher coverage in the offshore areas, particularly in Poland and in Germany. In many Member States there is an extensive geographical overlap between designated SACs and SPAs.

It is clear that more sites need to be designated in general, and especially in the EEZ and in low-salinity sub-regions if the Natura 2000 network is to be considered a representative MPA network with regard to the geographical distribution of sites.

Benthic marine landscape representation

Altogether, 60 benthic marine landscapes were identified in the Baltic Sea (Table 1 in Annex 8.2). Less than one third (19/60) of these benthic marine landscapes were found in quantities over the recommended minimum level of 20% within designated SACs and thereby two thirds (41/60) were found in quantities below 20%. As many as 13 were found in quantities of less than 2% (Figure 14, Table 5, see, also Annex 8.2).

The representation was only slightly improved when SPAs were also included in the assessment. Altogether 23/60 benthic marine landscapes were found in quantities over 20% within the designated Natura 2000 sites (SACs and SPAs) (Figure 14, Table 5).

Furthermore, it can be concluded that the 49 least common marine landscapes in the Baltic Sea are proportionally better represented than the 11 most common, dominating landscapes, e.g. 7 of the 11 most common landscapes have a representation below 2% (see Chapter 3.1.1 and Annex 8.2). This is not surprising since it does not require a large total area of protection to cover a large share of a rare landscape like *bedrock in the euphotic zone,* while it requires a huge area to cover the same relative coverage of a common landscape like *mud in the non-photic zone*. However, one may also question weather the same relative protection is needed for a common as a rare habitat or if rare habitat requires even higher relative protection. Out of the nine marine landscapes with the highest percentage of protection (category “good” or “high”) almost all landscapes are in the shallow euphotic zone, independent of substrate type, whereas the least protected landscapes are in the non-photic zone, in mud or hard clay substrates and often in low salinity areas.

Generally, most designated sites are established in the shallow euphotic zone. This also coincides with the geographical distribution of sites being dominated by coastal areas. The same trend is seen independent of bottom substrate type or salinity category. A very small proportion of the designated sites cover benthic marine landscapes in the deeper areas, below the euphotic zone (Figures 14 and 15). This bias towards shallow water and coastal areas can probably, at least to some extent, be explained by the fact that the marine Natura 2000 habitats listed in the annexes to the Habitats Directive are dominated by coastal habitat types (Estuaries 1130, Coastal Lagoons 1150, Large shallow inlets and bays 1160, Baltic esker islands 1610, Boreal Baltic islets and small islands 1620 and Boreal Baltic narrow inlets 1650). The Habitats Directive, as it is formulated to date, is evidently not designed to protect the full variety of habitats and species in the Baltic Sea and secure the establishment of a truly representative and coherent MPA network.

Table 5. *The representation of benthic marine landscapes within SACs only and SACs + SPAs summarized in five categories.*

Representation	Number of landscape types within Natura 2000 SACs	Number of landscape types within Natura 2000 SAC and SPA sites
Bad (<10%):	28 / 60	24 / 60
Poor (10-20%)	13 / 60	13 / 60
Moderate(20-30%)	10 / 60	6 / 60
Good (30-60%)	6 / 60	13 / 60
High (60-100%)	3 / 60	4 / 60

Addition of SPAs to the SAC network would mean only a slight improvement in the protection of benthic landscapes (Figure 14, Table 5). The inclusion of SPAs to the analysis increased the protection of the dominating landscapes only by a small percent. The only exception was *non-photic sand in 7.5-11psu salinity*, for which protection increased from 16% to 27% (Annex 8.2).

It can be further concluded that there is a difference in how well the designated sites cover different substrate types. Areas with sand as the dominating substrate are protected up to 15%, areas with hard bottom complex up to 12% and areas of bedrock up to 12%, whereas there is much lower level of coverage in areas where mud (3%) and hard clay (2%) are the dominating substrates (Figure 15). This may, at least partly, be explained by the fact that landscapes dominated by sand and hard bottom correlates quite well with the Natura 2000 habitat types listed in the annexes to the Habitats Directive (i.e. *Sandbanks that are slightly covered by sea water all the time* and *Reefs*). On the other hand, mud and hard clay which are the dominating bottom substrates in the Baltic Seas are not clearly associated with any Natura 2000 habitat, at least not below the euphotic zone.

It is clear that the full variety of benthic marine landscapes are not sufficiently represented in the existing Natura 2000 network, that more sites need to be designated in general, and especially in deeper offshore areas and in areas with mud and hard clay sediments if the Natura 2000 network is to be considered a representative MPA network with regards to its representation of benthic marine landscapes. The quantities of benthic marine landscapes in total and the quantity and percentage of each landscape type represented within Natura 2000 sites are summarised in Annex 8.2.

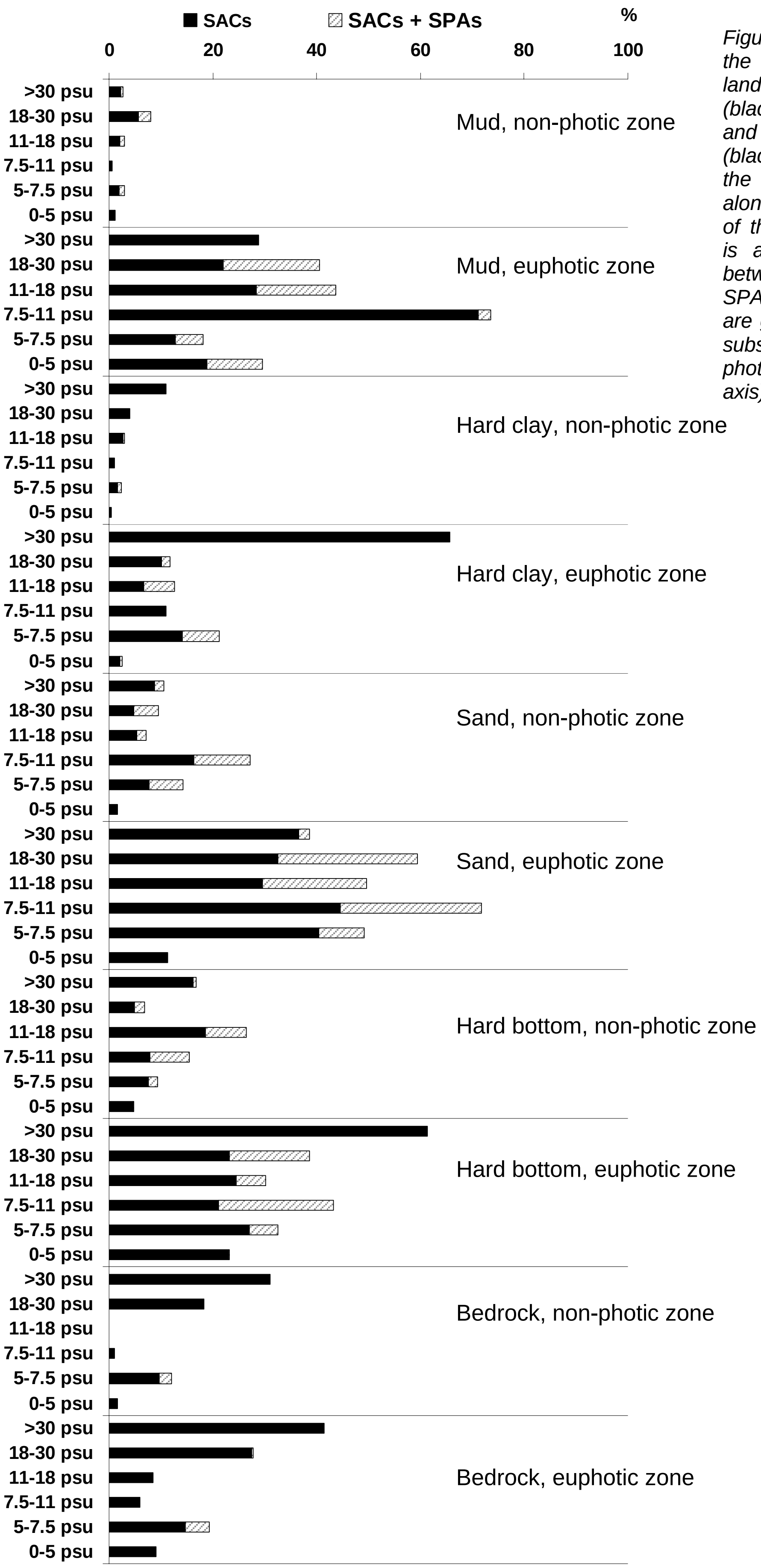


Figure 14. Proportion of the 60 benthic marine landscapes within SACs (black) and within SACs and SPAs combined (black+striped). Note that the coverage of SPAs alone cannot be read out of the graph since there is an overlap in areas between SACs and SPAs. Salinity categories are grouped according to substrate types and photic depths (vertical axis).

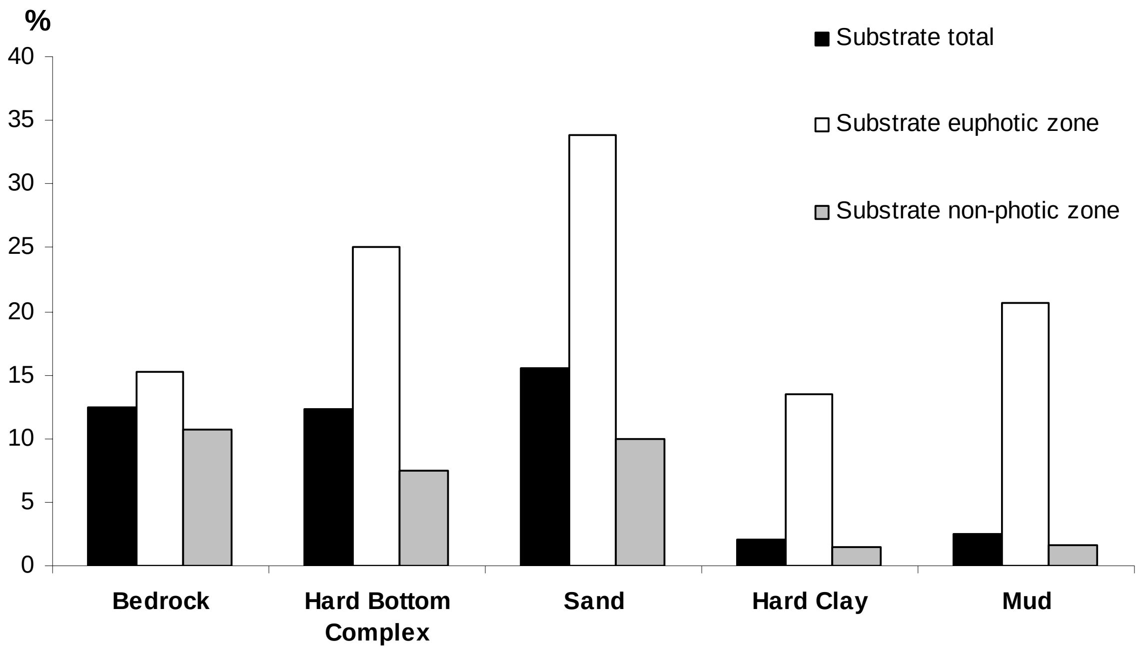


Figure 15. Proportion of bottom substrate types within SACs in the Baltic Sea area (black), in the euphotic zone (white) and in the non-photic zone (light grey).

Benthic marine landscape representation in the separate EU Member Sates
The benthic marine landscape representation was also analyzed country by country. Separate statistics for each of the Member States can be found in Annex 8.3.

It can be concluded that all the EU Member States around the Baltic Sea have severe gaps in the representation of the deep landscapes. Germany is the only country where the representation of most non-photic landscapes is over 20%. In Germany only *non-photic sand*, *non-photic hard-bottom* and *non-photic mud* have a coverage below 20%. Landscapes in the euphotic shallow waters were generally better represented in all countries.

There is extensive geographical overlap between SACs and SPAs in all countries, except Poland. The inclusion of SPAs in the analysis considerably increases the representation of many benthic marine landscapes in Poland. Also in Denmark, Estonia and Germany the addition of SPAs increases the representation of some landscapes.

Topographic and bed-form features
None of the topographic and bed-form features were found in quantities over 20% within the designated SACs (Figure 16). *Sandy mounds*, *complex mounds* and *bedrock mounds* are relatively common in designated areas with 18, 16 and 14% representation, respectively. There is much lower representation of *basins, clay mounds, valleys and holes*, and *slopes*.

A slight increase in the total representation of sandy *mounds, complex mounds, bedrock mounds* and *plains* can be seen if also SPAs are included in the assessment (Figure 16).

The dominating topographic features in the Baltic Sea are *plains* (47%), *basins* (22%) and *clay mounds* (13%). Other landscape features cover relatively small total areas, among these *troughs* (1%) and *bedrock mounds* (2%) are the least common (Figure 5). This can to some extent explain the relatively large percentage of protection of *sandy mounds, complex mounds* and *bedrock mounds*, since it does not require a very large total area of protection to cover a large share of these landscape types. The situation is the opposite for *plains* and *basins*, where a representative coverage requires a quite large total area.

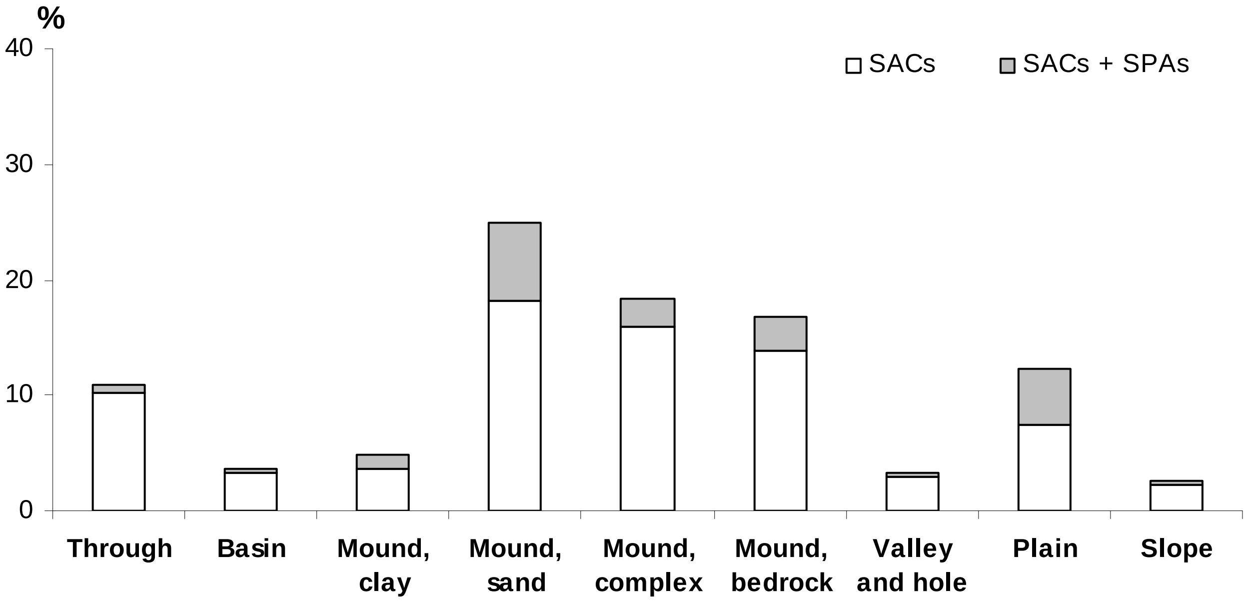


Figure 16. Proportion of each topographic bed-form feature that is covered by SACs (white) and combined SACs and SPAs (grey). Note that the amount of coverage of SPAs alone cannot be read out of the graph since there is geographical overlap between the two networks.

Coastal physiographic features

The coastal physiographic features cover only the near shore areas of the region (in total only 8% of the region, see Figure 7). It has already been concluded above that the coverage of designated Natura 2000 sites is far better in the coastal areas, compared to the offshore areas. This should be kept in mind when interpreting the results. *Archipelago* is the coastal feature with the most extensive distribution in the Baltic Sea (nearly 90% of the total coverage of the coastal physiographic features, see Figure 8).

Archipelagos together with *sounds* were found to be the feature with the lowest proportion of representation in SACs (14% and 8% respectively, Figure 17). As *archipelagos* cover a much larger area than the other coastal physiographic features, however, a larger total area is needed to achieve a representative protection of *archipelagos*.

Lagoons and lagoon-like bays, on the other hand, were found to be well represented in SACs (70%, Figure 17). This can to a large extent be explained by the fact that areas identified as *lagoons and lagoon-like bays* cover a very small part of the Baltic Sea (approx. 2%, Figure 8) and that Coastal lagoons (1150) and Large shallow inlets and bays (1160) are listed as an Annex I habitat under the Habitats Directive and thereby are in focus for protection in the Natura 2000 network. The largest *lagoons and lagoon-like bays* are primarily found in Estonia and Germany and are well covered by protected areas. *Estuaries* and *fjords* are also quite well represented, with over 20% coverage in SACs (Figure 17).

Including SPAs into the analysis almost doubled the coverage of *estuaries*. *Estuaries* are well known for their importance as bird breeding, resting and moulting sites. There is also a slight increase in the representation of *lagoons and lagoon-like bays, sounds* and *archipelagos*. Designating these SPAs also as SACs under the Habitats Directive, would increase the protection of estuaries extensively.

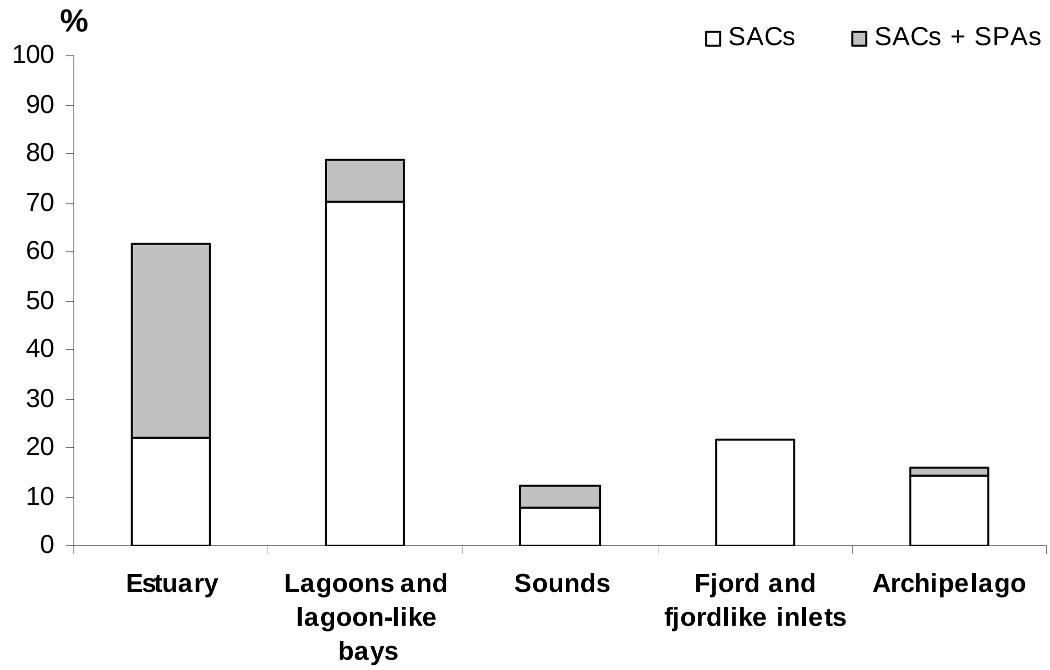


Figure 17. Proportion of coastal physiographic landscapes that are within SACs (black) and within combined SACs and SPAs (grey). Note that the coverage of SPAs alone cannot be read from the graph since there is overlap in areas between the two networks

There are also obvious differences in the representation of coastal features between different countries. For example, Estonia is a small country with little coverage of coastal physiographic features but a high representation of those within designated sites. In contrast, Finland has a relatively long coastline with extensive areas categorised as coastal features, dominated by archipelago, but a low proportion of the marine part of the archipelago has been captured in designated areas.

As mentioned before, the coastal physiographic features and topographic bed-form features were compared to the definitions of the Natura 2000 habitat classes, sandbanks, estuaries, coastal lagoons and reefs (Chapter 3.1.4). There was not a perfect match, but the maps can still be used as an indication of the probable presence of some of the Natura 2000 habitat types. This means that a gap identified in representation of one of the coastal and topographic features could give a valuable indication of the lack of protection of the corresponding Natura 2000 habitat type.

Representation results in summary (Natura 2000):
The Natura 2000 network is not representative with respect to its geographical distribution, or with respect to benthic marine landscapes.

1. The Natura 2000 network covers less than 20% of all sub-regions. The sub-regions with low salinity are least covered.
2. There is a significant difference between the EU Member States in the proportionate coverage of sites. Germany has the highest proportionate coverage of designated sites and it is the only country that has designated over 20% of its waters.
3. The geographical distribution of sites is heavily biased towards shallow coastal areas/territorial waters. This trend is seen throughout all countries except Germany.
4. As many as two thirds of the benthic marine landscapes are insufficiently represented within the Natura 2000 network (compared to the recommended minimum 20% representation level). The need to increase representation is, however, most obvious in landscapes in the non-photic zone and in landscapes dominated by mud and hard clay.
5. Also including SPAs to the SAC network would improve representation of some benthic marine landscapes especially in some countries, but would not greatly improve the overall representation since the two networks have an extensive geographical overlap.
6. The Habitats Directive as it is formulated to date, is not designed to establish a representative network since not all landscapes and habitat types are covered by the directive.

4.3.3 Results and discussion on the BSPA network assessment

Geographical representation
The proportion of HELCOM marine area designated or proposed as Baltic Sea Protected Area is fairly similar among the five large sub-regions, but very variable among the smaller HELCOM sub-regions (2-40%, Table 6). The five larger sub-regions have 8-12% covered by designated or proposed BSPAs. Kattegat and the Gulf of Finland have a coverage of more than 10%, whereas the Baltic Proper, the Bothnian Bay and the Bothnian Sea have 8% coverage each. Of the 18 HELCOM sub-regions, Gulf of Gdansk, the Quark, Archipelago Sea, Kiel Bay and Bay of Mecklenburg have a BSPA coverage of 20% or more (Table 6), while Eastern and Western Gotland Basin, Bothnian Bay and Little Belt have below 5% coverage.

Table 6. Proportion of marine area designated as BSPAs of the total marine area in HELCOM marine area sub-regions and larger sub-regions used in the BALANCE project.

HELCOM 18 Sub-regions	BSPA coverage (%)	Sub-regions	BSPA coverage (%)
The Gulf of Gdansk	20	Baltic Proper	8
The Gulf of Riga	14		
Eastern Gotland Basin	3		
Western Gotland Basin	2		
Southern Baltic Proper	9		
Northern Baltic Proper	9		
Bothnian Bay	4	Bothnian Bay	8
The Quark	40		
Bothnian Sea	6	Bothnian Sea	8
Åland Sea	7		
Archipelago Sea	22		
Gulf of Finland	11	Gulf of Finland	11
Kattegat	6	Kattegat	12
The Sound	7		
Little Belt	4		
Great Belt	19		
Kiel Bay	26		
Bay of Mecklenburg	26		

Since the 18 sub-regions are smaller parts of the five large sub-regions, the distribution between these sub-regions can be seen as a measure of how evenly distributed the sites are within the large sub-regions. For example, when the large Bothnian Bay sub-region is split into the smaller sub-regions, it can be seen that as much as 40% of the Quark is covered, whereas only 4% of the rest of the Bothnian Bay is covered.

Moreover, the proportionate coverage of BSPAs differs considerably among the HELCOM contracting parties (Figure 18). Germany has designated or proposed a large proportion (38%) of the total water area, compared to most of the other countries. Sweden, Russia and Latvia have designated or proposed less than five percent of their total marine area (4%, 4% and 3% respectively). These results are very similar to the results of the Natura 2000 network assessment.

Coastal areas (territorial waters) are generally much better represented than offshore areas (EEZ) (Figure 18). Altogether, 20% of the territorial waters and 2% of the EEZ within HELCOM marine area are designated or proposed BSPAs. The same trend, with a higher proportion of designation in territorial waters than in the EEZ, is seen throughout all the countries except in Germany, where 39% of the EEZ is designated. Denmark, Finland, Latvia, Lithuania and Russia have no area designated in the EEZ, whereas Sweden, Estonia and Poland have very limited designated area. It is also important to remember that a number of the BSPAs included in the analysis are not designated (only proposed) and still do not have legal protection,

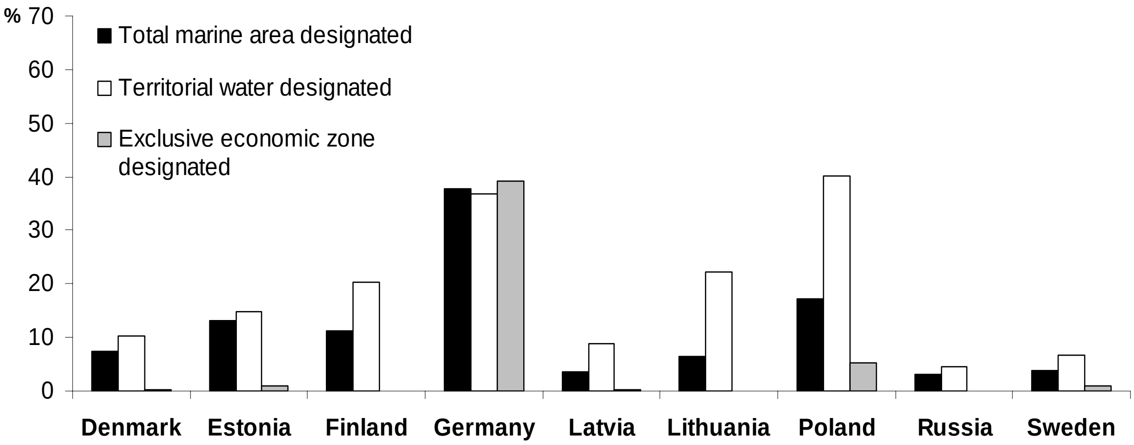


Figure 18. The coverage of Notified and Designated as well as Proposed BSPAs in the marine areas of HELCOM contracting parties measured as a proportion of the total marine area (black), territorial water (white) and exclusive economic zone (grey).

Benthic marine landscape representation

Only one third (19/60) of the benthic marine landscapes were found in quantities over 20% within the designated and proposed BSPAs, (i.e. in the category ‘moderate’) and thereby as many as two thirds (41/60) were found in quantities under 20% (Table 7). The 19 landscapes having "good" or "moderate" representation comprise mostly substrate types in the euphotic zone (Figure 19).

Only one of the 11 landscapes dominating the Baltic Sea, i.e. non-photic sand in 7.5-11 psu, had a proportionate coverage of more than 20% whereas two of the dominating landscapes, i.e. *non-photic hard bottom complex in 0-5psu* and *in 5-7.5psu*, had a coverage of 12% (Figure 19).

Moreover, there is a difference in how well the BSPA network represents different substrate types (Figure 20). Areas where the bottom substrate is dominated by bedrock (23%) and hard bottom complex (15%) or sand (16%) have the highest proportionate coverage, whereas there is much lower representation in areas where mud (4%) and hard clay (4%) are the dominating substrates. These results are more or less similar to the results of the Natura 2000 assessment. All bottom substrates are better represented in the euphotic zone than in the non-photic zone. This result coincides with the geographical distribution of sites being highly biased towards coastal areas/territorial waters (Figure 18).

Table 7. The representation of benthic marine landscapes within BSPAs summarized in five categories.

Representation	Number of landscape types within BSPAs
Bad (<10%):	33 / 60
Poor (10-20%)	8 / 60
Moderate (20-30%)	12 / 60
Good (30-60%)	7 / 60
High (60-100%)	0 / 60

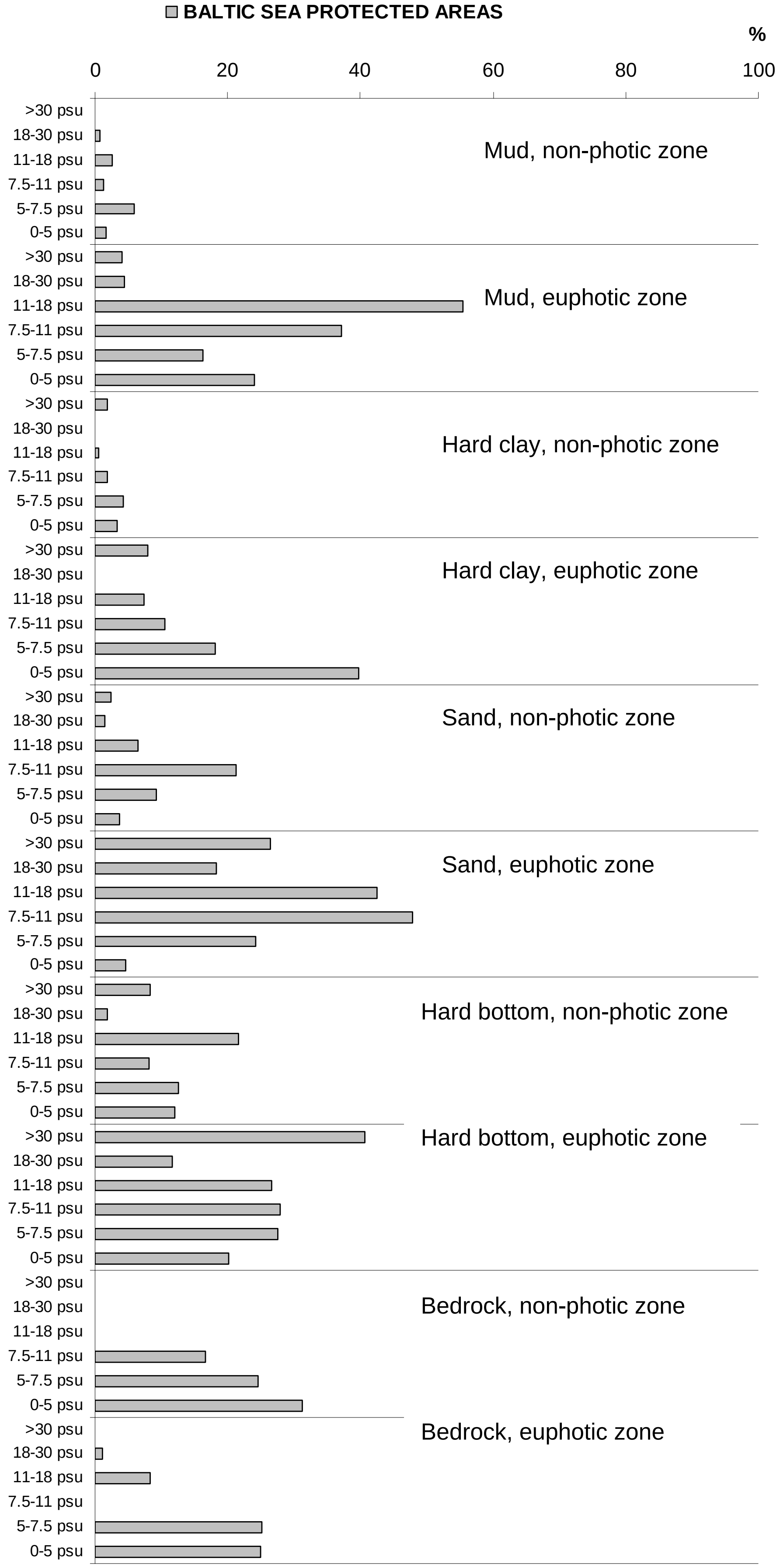


Figure 19. Proportion of the 60 benthic marine landscapes represented within BSPAs (horizontal axis). Salinity categories are grouped according to substrate type and photic depths (the vertical axis).

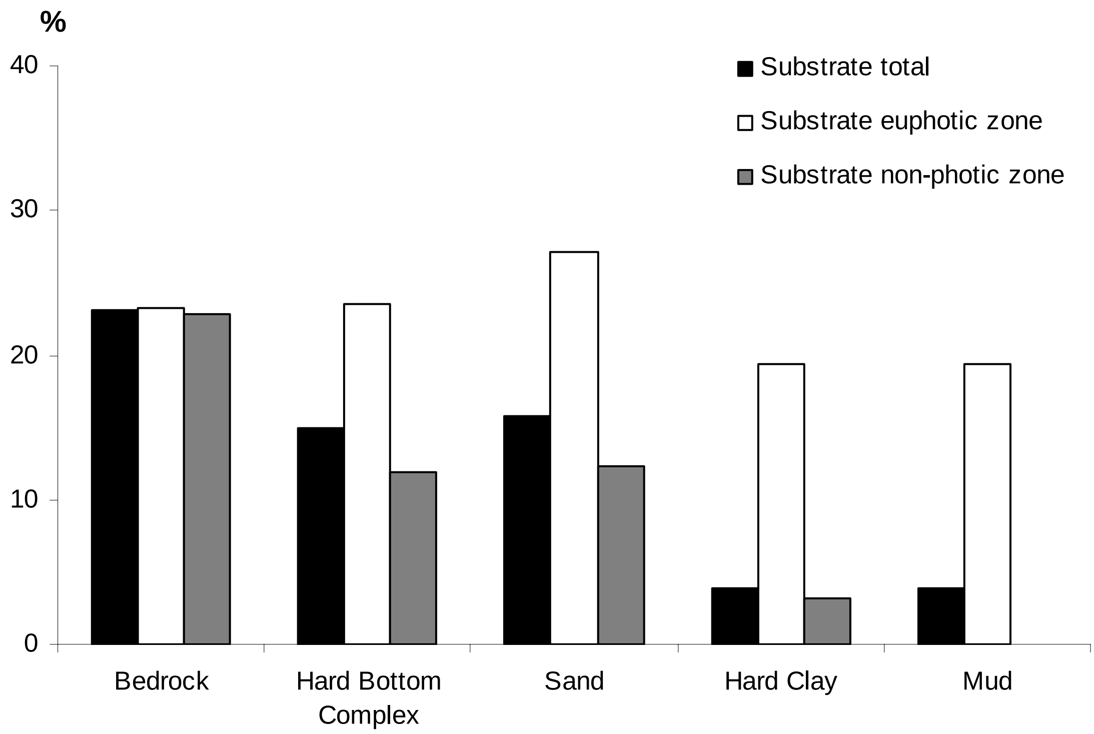


Figure 20. The proportion of each substrate type within BSPAs in the whole Baltic Sea (black), in the euphotic zone (white) and in the non-photic zone (grey).

Representation results in summary (BSPA):

1. The BSPA network (notified, designated and proposed sites) is not representative with respect to its geographical distribution, or with respect to its representation of benthic marine landscapes.
2. The BSPA network covers less than 20% of all the five large sub-regions.
3. The proportionate coverage of sites differs significantly between the HELCOM Contracting Parties.
4. The geographical distribution of sites is highly biased towards coastal areas/territorial waters.
5. As many as two thirds of the benthic marine landscapes are insufficiently represented within the BSPA network (compared to the recommended minimum 20% representation level). The need to increase representation is, however, most obvious in landscapes in the non-photic zone and in landscapes dominated by mud and hard clay.
6. It is important to remember that a number of the BSPAs included in the analysis are not designated (only proposed) and still do not have legal protection, which means that the results presented are a clear overestimation of the real level of protection.
7. These results are very similar to the analysis of the Natura 2000 network

4.4 Assessment of replication

Replication of different features within an MPA network is important to ensure natural variation of the feature, at landscape, habitat, species or genetic level (Airamé et al. 2003, OSPAR 2005). Replication increases the representation of the given feature and can be considered as an insurance factor. Several replicates spread the risk against damaging events like oil spills and also against long-term changes (Allison et al. 2003). The replication of a feature within a single MPA should be taken into account when planning MPA boundaries, whereas the replication of a feature between sites within the network of MPAs ensures a higher level coherence.

Replication increases the number of connections between sites and therefore also enhances connectivity of the network (OSPAR 2005, Hastings & Botsford 2006). In their model of population persistence, Hastings and Botsford (2006) show that four replicates, connected to each other, are more persistent than three or fewer. They argue that the set of four sites consists of several possible networks of two or three sites. In the Great Barrier Reef, Fernandes et al. (2005) propose that 3-4 no-take areas for most bioregions should be founded in a network to maintain effective conservation. They add, however, that the actual amount of replication must depend on bioregional characteristics.

As noted above, replication is closely interlinked with representation and connectivity, but also with adequacy. A replicate should be adequate in size in order to support the communities of species it is intended to protect. A network of MPAs should also ensure the representation of the genetic variation of the features and therefore the network needs to represent the whole range of the feature. The feature should therefore be protected in all geographic regions where it occurs. This enhances replication *per se* but also representation. In order to maintain connectivity between the replicates, more than one replicate is often needed in each biogeographic region.

Defining a replicate can be somewhat problematic. Should all protected habitat or landscape patches of adequate size be considered separate replicates or does a cluster of closely interlinked patches of the same habitat or landscape form one replicate? A replicate can also be defined by MPA boundary (all patches of a particular landscape within an MPA form a replicate) but this can be problematic as the MPAs differ in size to a large extent. These issues need to be considered on a case-by-case basis by identifying the requirements of the features that the network aims to protect.

Replication criteria applied

Marine landscape scale:
Ideally, the minimum size for a patch to be considered a replicate should be based on the requirements of the assessed species or habitats. For benthic marine landscapes this kind of an approach was impossible. Therefore a theoretical size, based on the resolution of the landscape maps, was chosen: The minimum size for a landscape patch to be considered a replicate was set at 24 hectares (6 pixels). All protected landscape patches larger than this were considered separate replicates (even if they were close to each other or within the same MPA). This is not an ideal approach, but still gives an overview of the amount of replication of different features in different regions of the Baltic Sea.

No division into sub-regions was used in the assessment as the benthic marine landscapes include the salinity regimes of the Baltic Sea that form a natural division into "regions". As the adequate number of replicates should also be defined by the species or the habitat assessed, no specific number for an adequate amount of replicates was set, but a low number of replicates indicates a possible gap in replication.

In order to assess whether the replicates were within only one or few MPAs (within-site replication) or distributed between several MPAs (between-site replication) the number of MPA hosting the replicates was also calculated.

4.4.1 Methodology

The generalized benthic marine landscape dataset was first masked with the layer containing the SACs in order to select only those landscape patches occurring within SACs. The number of landscape patches and the mean sizes for patches within the SACs was calculated for each landscape type. The same analyses were then carried out for SACs and SPAs together, as well as for BSPAs (designated and notified BSPAs + proposed by contracting parties) separately (see Chapter 2.2). Additionally, the total number of patches (also unprotected patches included) was calculated for each marine landscape in order to compare the total number of patches to the number of protected patches. The number of MPAs hosting the replicates of the different benthic marine landscapes was also calculated.

4.4.2 Results and discussion on the Natura 2000 network assessment

The number of patches of the benthic marine landscapes within the Natura 2000 network in the Baltic Sea region varied from none to several hundred (Table 8). Generally, the numbers of replicates were rather high, which most likely results from the natural patchiness of many of the landscapes, both inside and outside MPAs. Comparing the number of replicates of each landscape to the total number of patches gives an idea of the proportion of patches protected. It is important, however, to keep in mind that most of the patches are only partly protected and may therefore not be adequate in supporting viable communities of species. The representation values presented in the previous chapter (Chapter 4.3) better represent the overall protection of the landscapes. Comparing the number of replicates in different salinity regimes gives an idea of the geographical distribution of the replicates of different substrate/light combinations.

Three of the hard clay landscape types had less than 10 replicates within SACs, two of them in the euphotic zone. The bedrock landscapes also had very little replication, in both euphotic and non-photic areas, except in areas with 5-7,5 and >30psu salinity. For most of these landscapes, the total number of patches was also rather low. When it comes to landscapes occurring in only a few patches, including all or at least most of them within the network would be important.

The fact that many replicates are located within the same MPA makes it important to look at the number of MPAs that host the replicates. This gives an indication of the between-site replication that is important to secure a larger scale replication, for example to protect against catastrophic events in an area and to capture the full variation of species and habitats. The result shows that for those marine landscapes that had the least replicates, they were often found within different SACs (landscapes highlighted in yellow in Table 8). An exception was *non-photic hard clay in 18-30psu salinity* as all four replicates of this landscape were within the same site. For *non-photic mud in 7.5-11psu salinity* and *non-photic bedrock in>30psu salinity* the between-site replication was low, as they both had tens of replicates that were located in only four and seven SACs respectively.

Adding the SPAs to the SAC network further increased the number of replicates for many benthic marine landscapes. This enhancement, however, is probably not critical to the network as it enhanced replication of the landscapes already well replicated within SACs.

Table 8 (continues on the next page). Number of benthic marine landscape replicates within SACs and within the SACs and SPAs combined. The number of replicates shows the number of protected patches over 24ha.The number of MPAs shows the number of Natura sites that host these patches and the mean size of the protected patches is presented in the last column. The landscapes that have less than 10 replicates are highlighted in yellow. The landscapes that were used in the connectivity analyses (Chapter 4.5) are highlighted in orange.

Benthic marine landscapes			Total number of patches	Number of replicates SAC / SAC+SPA	Number of MPAs SAC / SAC+SPA	Mean size (ha) of a protected patch SAC / SAC+SPA
Substrate	**Light**	**Salinity**				
Bedrock	**Euphotic**	**0-5psu**	77	13 / 13	6 / 6	135 / 135
		5-7.5psu	1255	233 / 289	97 / 99	189 / 206
		7.5-11psu	26	8 / 8	6 / 6	129 / 129
		11-18psu	4	1 / 1	1 / 1	408 / 408
		18-30psu	32	8 / 8	5 / 5	106 / 106
		>30psu	137	65 / 65	11 / 9	84 / 84
	Non-photic	**0-5psu**	37	4 / 4	2 / 2	46 / 46
		5-7.5psu	1006	197 / 238	50 / 55	203 / 211
		7.5-11psu	208	6 / 6	4 / 4	151 / 151
		11-18psu	1	0 / 0	0 / 0	0 / 0
		18-30psu	9	2 / 2	2 / 2	88 / 88
		>30psu	203	78 / 78	7 / 7	272 / 272
Hard bottom complex	**Euphotic**	**0-5psu**	918	194 / 201	90 / 76	522 / 506
		5-7.5psu	824	310 / 336	123 / 112	576 / 642
		7.5-11psu	120	83 / 94	35 / 34	273 / 495
		11-18psu	291	115 / 133	33 / 29	472 / 501
		18-30psu	364	128 / 176	40 / 39	405 / 489
		>30psu	27	21 / 21	10 / 10	339 / 339
	Non-photic	**0-5psu**	378	165 / 160	41 / 39	276 / 297
		5-7.5psu	783	191/ 213	51 / 53	914 / 1015
		7.5-11psu	235	45 / 58	14 / 12	938 / 1427
		11-18psu	209	66 / 75	27 / 22	577 / 719
		18-30psu	296	66 / 79	20 / 22	117 / 139
		>30psu	136	34 / 35	10 / 11	287 / 288

Table 8 continues						
Sand	**Euphotic**	**0-5psu**	263	83 / 84	44 / 43	279 / 276
		5-7.5psu	299	143 / 161	68 / 60	1256 / 1358
		7.5-11psu	149	123 / 113	39 / 33	1242 / 2174
		11-18psu	205	67 / 81	29 / 25	1329 / 1846
		18-30psu	321	120 / 136	51 / 54	1488 / 2401
		>30psu	78	49 / 53	13 / 13	571 / 558
	Non-photic	**0-5psu**	133	35 / 37	15 / 14	250 / 238
		5-7.5psu	212	113 / 133	39 / 40	1707 / 2661
		7.5-11psu	98	44 / 46	16 / 15	8679 / 13861
		11-18psu	166	61 / 65	23 / 19	394 / 496
		18-30psu	260	74 / 105	22 / 23	225 / 321
		>30psu	109	49 / 52	20 / 20	447 / 509
Hard Clay	**Euphotic**	**0-5psu**	203	12 / 16	10 / 11	60 / 54
		5-7.5psu	881	225 / 263	96 / 94	159 / 211
		7.5-11psu	13	3 / 3	2 / 2	369 / 369
		11-18psu	11	1 / 3	1 / 2	80 / 59
		18-30psu	50	10 / 12	7 / 6	161 / 157
		>30psu	26	10 / 10	8 / 8	377 / 377
	Non-photic	**0-5psu**	116	10 / 12	6 / 7	156 / 193
		5-7.5psu	535	156 / 185	55 / 61	471 / 565
		7.5-11psu	173	30 / 32	3 / 4	1053 / 998
		11-18psu	55	14 / 11	5 / 5	630 / 857
		18-30psu	36	4 / 4	1 / 1	468 / 468
		>30psu	221	73 / 73	8 / 8	133 / 133
Mud	**Euphotic**	**0-5psu**	413	81 / 83	33 / 33	251 / 385
		5-7.5psu	1563	168 / 190	88 / 82	281 / 354
		7.5-11psu	52	34 / 35	10 / 10	967 / 970
		11-18psu	125	54 / 69	12 / 15	368 / 448
		18-30psu	352	128 / 135	34 / 35	278 / 486
		>30psu	225	68 / 68	15 / 11	62 / 62
	Non-photic	**0-5psu**	172	45 / 47	23 / 21	341 / 339
		5-7.5psu	667	160 / 174	71 / 72	524 / 715
		7.5-11psu	120	39 / 40	4 / 5	723 / 746
		11-18psu	68	51 / 47	19 / 15	824 / 1256
		18-30psu	145	93 / 103	34 / 35	345 / 440
		>30psu	154	111 / 109	24 / 21	316 / 370

In summary, the number of replicates of most benthic marine landscapes was found to be relatively high within the Natura 2000 network, but many of the replicates include only parts of the landscape patches and may therefore not be of sufficient size. Also, the fact that the replicates of some marine landscapes occurred within only a few MPAs limits the between-site replication. Only hard clay and bedrock landscapes were found to have low numbers of replicates.

Defining specific criteria for replication at marine landscape level turned out to be rather problematic. First of all, setting the minimum size for a landscape patch was difficult as the minimum size for a replicate should be based on requirements of a species. As marine landscapes are geophysically defined entities that host a variety of species, this task was difficult. The set limit of 24 hectares may have been too small for some landscapes (or rather for species occurring in them) to support viable communities of some species, but the size limit may have been too large, for instance, for bedrock landscapes in the northern Baltic Sea. Although extensive archipelago areas in the northern Baltic Sea mainly consist of bedrock, they generally occur in mosaic-like landscapes where separate bedrock patches may be very small. Therefore, small patches of bedrock may have been missed when developing the marine landscape maps due to the coarse resolution of the datasets used. They may have also been missed when generalizing the landscape maps according to the set criteria (dissolving areas smaller than 24 hectares into their surroundings). As a result, the assessment most likely gives an underestimation of the true number of replicates of low-salinity bedrock landscapes.

Another difficult question was setting a value for an adequate amount of replicates. As replication is needed to secure the natural variation of the species as well as to protect the species against catastrophic events, more important than having a huge number of replicates is geographically placing the replicates in a way that they are spread across the whole distribution range of the landscapes. In this assessment, the different salinity regimes were used as "proxies" of the distribution. If a certain substrate/ light combination had replicates in all salinity regimes it occurred in, it was assumed that it's whole natural range was covered. As the salinity regimes are rather large entities, however, this may not be the case. Furthermore, when considering adequate spacing between the replicates, the dispersal distances of species occurring in the landscapes or habitats should be taken into account. This means that the need for replication should to be considered together with connectivity.

In conclusion, the need for more replication can be best identified spatially, and conservation feature by conservation feature, by looking at the distribution ranges of species and comparing that to the distribution of areas where that particular species is protected, and also considering the species dispersal abilities (also see the case study in chapter 5). When the number of features to be included in the assessment is high, however, (in this case 60 landscapes) some approximation of replication can still be achieved by using the methods presented in this assessment, i.e. dividing the area of interest into regions of ecological relevance (as the salinity regimes in this assessment), by calculating the number of replicates in each region and comparing that number to the total number of the patches of that particular landscape as well as to the number of MPAs in which they occur. That gives an indication of both the total replication in the network and the replication between sites.

The question of what is actually a replicate was also widely discussed during the project. For example, grouping all patches of a particular landscape within the same site to form one replicate was considered and tested. As the MPAs vary a lot in size, however, it turned out in some cases that even the patches occurring within the same large site were too far from each other to be considered as one replicate. Another approach that was considered was to define all protected patches of a particular landscape within a specified distance (e.g. 10km) from each other as one replicate, no matter whether they were within the same MPA or different MPAs. No suitable methodology for this was found, however, as it proved difficult to draw boundaries between the clusters of patches, when the aim was that *all patches* within a cluster should be at least within a specified distance to *all other patches* within the same cluster (not just to its closest neighbours).

It can be concluded that defining what is actually a replicate needs further development, and as for all other critical criteria when considering replication, the decision should be based on the characteristics of those species considered for protection, e.g. their distribution and dispersal abilities.

Replication results in summary (Natura 2000):

1. According to the assessment, hard clay and bedrock landscapes in some areas have relatively few replicates within the Natura 2000 network. Other landscapes have relatively high numbers of replicates, but these often includ only parts of landscape patches, not whole patches. Furthermore, some landscapes that have relatively many replicates, all of them are within only few sites, indicating bad between-site replication.

2. Assessing replication at the landscape level was found to be problematic, as defining what is actually a replicate, setting a minimum size for a replicate as well as defining adequate spacing between replicates should be done feature by feature based on individual species characteristics.

4.4.3 Results and discussion on the BSPA network assessment

Replication of the benthic marine landscape patches within the BSPA network varied from zero to some hundreds (Table 9). In general, when comparing to the Natura 2000 network, replication was poorer in the BSPA network as several landscape types had less than ten replicates within the network. As the BSPAs are larger and fewer than the Natura 2000 sites in the Baltic Sea, the within-site replication of landscapes often played an important role and the number of sites hosting the replicates (between-site replication) was often low.

The majority of the poorly replicated landscape types were again bedrock and hard clay landscapes. The euphotic bedrock landscapes had none or only one replicate in the four salinity regimes, and the same applied for non-photic bedrock landscapes in three salinity regimes, and for both euphotic and non-photic hard clay landscapes in two salinity regimes. Poor replication was also found in other bottom substrates.

As discussed in the chapter 4.4.2, the need for replication and the minimum size for a replicate are strongly dependent on species characteristics. Therefore an assessment carried out on a broad marine landscape level can only give a rough overview of the replication of different benthic marine landscape types in different areas.

This assessment, however, indicates that the replication of many of the benthic marine landscapes, especially hard clay and bedrock landscapes, within the BSPA network is relatively poor. Moreover, as mentioned before, it is also important to remember that a number of the BSPAs included in the analysis are still only proposed and do not have legal protection, which means that the result presented probably is an overestimation of the replication.

Table 9. (continues on the next page). Number of benthic marine landscape replicates within BSPAs. The number of replicates shows the number of protected patches over 24ha. The number of MPAs shows the number of BSPAs that host these patches. The mean size of the replicates is presented in the last column. The landscape types that have less than 10 replicates are highlighted in yellow. The landscapes that were used in the connectivity analyses (Chapter 4.5) are highlighted in orange.

Benthic marine landscapes			Total number of patches	Number of Repli-cates in BSPAs	Number of BSPAs	Mean size of a protected patch In BSPA
Substrate	**Light**	**Salinity**				
Bedrock	**Euphotic**	**0-5psu**	77	20	2	235
		5-7.5psu	1255	334	13	228
		7.5-11psu	26	0	0	0
		11-18psu	4	1	1	432
		18-30psu	32	0	0	0
		>30psu	137	0	0	0
	Non-photic	**0-5psu**	37	17	2	189
		5-7.5psu	1006	260	14	395
		7.5-11psu	208	11	2	1424
		11-18psu	1	0	0	0
		18-30psu	9	0	0	0
		>30psu	203	0	0	0
Hard bottom complex	**Euphotic**	**0-5psu**	918	95	7	942
		5-7.5psu	824	256	19	711
		7.5-11psu	120	35	8	857
		11-18psu	291	69	13	693
		18-30psu	364	30	8	713
		>30psu	27	8	5	602
	Non-photic	**0-5psu**	378	77	8	1595
		5-7.5psu	783	169	22	1890
		7.5-11psu	235	50	7	897
		11-18psu	209	44	9	991
		18-30psu	296	17	4	157
		>30psu	136	5	3	1018
Sand	**Euphotic**	**0-5psu**	263	24	5	433
		5-7.5psu	299	134	24	979
		7.5-11psu	149	49	9	3342
		11-18psu	205	54	12	1765
		18-30psu	321	29	8	3413
		>30psu	78	10	5	1577
	Non-photic	**0-5psu**	133	8	3	2691
		5-7.5psu	212	107	20	2227
		7.5-11psu	98	27	7	18970
		11-18psu	166	37	8	751
		18-30psu	260	14	6	369
		>30psu	109	12	6	323

Table 9 continues						
Hard clay	**Euphotic**	**0-5psu**	203	39	2	411
		5-7.5psu	881	214	15	215
		7.5-11psu	13	3	2	369
		11-18psu	11	1	1	92
		18-30psu	50	0	0	0
		>30psu	26	2	1	164
	Non-photic	**0-5psu**	116	32	3	514
		5-7.5psu	535	162	23	1259
		7.5-11psu	173	43	4	1336
		11-18psu	55	11	3	128
		18-30psu	36	0	0	0
		>30psu	221	1	1	716
Mud	**Euphotic**	**0-5psu**	413	35	4	845
		5-7.5psu	1563	273	14	247
		7.5-11psu	52	12	4	1436
		11-18psu	125	44	11	618
		18-30psu	352	22	5	288
		>30psu	225	3	3	85
	Non-photic	**0-5psu**	172	20	5	1198
		5-7.5psu	667	139	22	2086
		7.5-11psu	120	29	6	2725
		11-18psu	68	26	10	1973
		18-30psu	145	14	5	272
		>30psu	154	4	4	267

Replication results in summary (BSPA):

1. According to the assessment, especially hard clay and bedrock landscapes in some areas have relatively few replicates within the BSPA network. Gaps in replication were also found for other landscapes. As BSPAs are generally larger and fewer than the Natura 2000 sites, the within-site replication is more common than between-site replication.

2. Generally, replication of landscapes is poorer than within the Natura 2000 network

3. Assessing replication at the landscape level was found to be problematic, as defining what is actually a replicate, setting a minimum size for a replicate as well as defining adequate spacing between replicates should be done feature by feature based on individual species characteristics.

4.5 Assessment of connectivity

Classical metapopulation theory predicts that connected populations persist longer than isolated populations (Molofsky & Ferdy 2005). As distance increases between two populations, the extinction risk increases exponentially, whereas the closest populations do not necessarily have the longest persistence (Molofsky & Ferdy 2005). Marine metapopulations can be interconnected by pelagic larval dispersal (Botsford et al. 2003), by drifting individuals, and by actively swimming organisms. They are usually connected at larger spatial scales than the terrestrial ones (Kinlan et al. 2005 and references therein, Ockelmann & Dinesen, unpublished).

The connectivity of populations may occur via drifting larvae or mobile, floating or rafting adults, depending on species (see Martin et al. 2006, Bergström L. et al. 2007). According to a review by Grantham et al. (2003), 85% of larvae (rocky shore intertidal and subtidal and sandy subtidal) of macroinvertebrate species have a planktonic larval stage in the North American west coast. In sandy intertidal, only 37% of the species have planktonic larval stage. Instead, the proportion of mobile adult stages is highest in the sandy intertidal environment: c. 80% (Grantham et al. 2003). A similar trend was suggested for Danish waters by Thorson (1946). It seems, however, that in low-salinity brackish water where many freshwater species occur, the trend cannot be seen. For example, many rocky habitat crustaceans as well as some snails, both common in the Baltic Sea, lack a planktonic stage.

Active swimming as well as floating and rafting by clinging to floating objects (detached algae, tree trunks, ship hulls, ice) connects populations of many species. These happen at a much smaller scale, however, than planktonic drifting. Baltic fish species, many of which disperse at adult stage, show genetic differences across the basin. Such species are flounder (*Platichtys flesus*), perch (*Perca fluviatilis*), northern pike (*Esox lucius*), pikeperch (*Sander lucioperca*), Baltic herring (*Clupea harengus membras*), and sea-spawning white fish (*Coregonus lavaretus*) (Nesbø et al. 1998, Bekkevold et al. 2005, Laikre et al. 2005, Florin & Höglund in press, Säisä et al., unpublished data, Björklund et al., unpublished data). In contrast, genetic studies on turbot (*Psetta maxima*) showed no differentiation, although the species has strong homing behaviour (Florin & Höglund 2006). Migration distances of common Baltic fish species are reviewed in Bergström L. et al. (2007). In their review on genetic diversity, Johannesson and André (2006) list dispersal potentials for an array of Baltic species of marine origin. An extreme example of adult swimming in the Baltic scale is salmon (*Salmo salar*), which migrates 1600km south, almost the whole length of the Baltic Sea, from the river mouths of the Bothnian Bay to its adult feeding grounds (Kallio-Nyberg et al. 1999). Typical floaters are bivalve post-larvae (Nelson 1925, Sigurdsson et al. 1976, Beukema & de Vlas 1989) and *Hydrobia* snails (Highsmith 1985). Many invertebrate species, mobile or immobile, are found rafting on floating seaweeds (Highsmith 1985, Salovius et al. 2005, authors' observations). The drifting and floating algae have increased all around the Baltic Sea due to coastal eutrophication. Thereby, the potential for rafting in the Baltic Sea has probably increased.

A model by Cowen et al. (2006) predicts that larval dispersal distances for a variety of reef fishes are 10-100 km. In a current with a flow speed of 0.1 m s^{-1}, larvae may, however, drift hundreds of kilometres during 30 days, which is quite usual time period for several species (Thorson 1946, Grantham et al. 2003, Palumbi 2003). In sounds, the current velocities can be much higher, from 0.5 to 2.5 m s^{-1}, which enables longer dispersal distances for many organisms. Generally, the dispersal is slower near the sea bottom because of slower water flows (Shanks et al. 2003). Mortality over the whole duration in plankton has been estimated to be as high as 90-99% for decapod larvae (Rumrill 1990, Morgan 1995, Marta-Almeida et al. 2006). Thus, the longer the distance between sites, the fewer larvae reach it. In the Baltic Sea there are some fish species that have true planktonic larvae. For instance, Baltic herring has pelagic larvae, which may drift several hundred kilometres over a few months (Johannesen & Moksness 1991). One may, however, question if the larvae are really passive over such a long time (e.g. Urho 1992), but, nevertheless, the potential transport routes of the larvae are certainly of importance to the MPA network. The Baltic sprat and cod larvae are known to drift long distances by the surface currents when hatched larvae migrate to surface layers to feed (Bekkevold et al. 2005, Voss et al. 2006).

Seaweeds disperse by drifting individuals, by parts of them or by microscopic propagules (spores, gametes, zygotes etc). Seaweed dispersal is usually considered limited (less than 30 m, e.g. *Fucus vesiculosus* and *F. serratus*; Zechman & Mathieson 1985 and references therein, Reed et al. 1988, Fletcher & Callow 1992, Norton 1992, Serrao et al. 1996, Malm et al. 2001), but long-distance dispersal (10-35 km) has been observed for many species (e.g. *Ulva* spp., *Sargassum* sp., *Ectocarpus* sp., *Macrocystis* sp.; Zechman & Mathieson 1985, Norton 1992, Gaylord et al. 2002). Eelgrass *Zostera marina* has relatively long dispersal: seed dispersal or floating mature plants can seed new populations over distances of tens of kilometres (Harwell & Orth 2002). In the northern Baltic Sea, where eelgrass does not produce seeds, the dispersal is limited to reattachment of detached plants, which seems to be rare (Olsen et al. 2004, C. Boström, pers. comm.). The genetic isolation of geographically close (5 km) populations in the northern Baltic Sea indicates that the current populations are old and new populations are very scarce. In contrast, the eelgrass populations in the southern Baltic Sea are genetically very similar even over distances of 75 km between the populations (Olsen et al. 2004), indicating better connectivity. Dispersal of aquatic plants, both algae and angiosperms, via avian intestinal tract and externally on feathers is probably of great importance; particularly stoneworts *Chara* spp. that were shown to survive well in the intestine of ducks and waders (a review of avian transport by Figuerola & Green 2002). This would enable long-distance dispersal, at least during migrations.

There are some estimates available on how close to each other the MPAs should be in order to support dispersal of species between separate areas. Halpern et al. (2006) suggest a maximum of 20-200 km, Shanks et al. (2003) 20 km, and Palumbi (2004) 10-100 km for invertebrates and 50-200 km for fish. The estimates rely on the known migration distances of species (including larval dispersal) and, thus, depend on the features for which the network is established. Botsford et al. (2001) as well as Halpern et al. (2006) state that, unless one is fairly certain of the dispersal distance, the safest way is to have the MPAs 25 kilometres from each other.

As presented above, drifting with currents and other water movements is an important dispersal strategy in the marine environment. Therefore not only distance between protected areas, but also direction and strength of currents determine whether the species will be able to disperse from one area to another. In the broad scale assessment on marine landscape level presented here, only distance between sites has been used to determine connectivity between sites. An example of using a hydrodynamic model and tracers to illustrate the movement of larvae and the upstream downstream ordering of MPAs is presented as a case study in chapter 4.5.4 and more thoroughly in another BALANCE report by Bendtsen et. al (2007).

Connectivity criteria applied

Marine Landscape scale:
Connectivity between MPAs is defined by the dispersal abilities of different species. Therefore, a twofold approach was chosen to assess connectivity:

a) 25 km approach: As a first step in this assessment, the connectivity between landscapes is presented as a theoretical showcase. Five wide-spread benthic marine landscape types were chosen for the analysis. They represent different combinations of substrate, salinity and photic depth. Their representation within the Baltic Sea MPA networks varies (Table 10). Based on the scientific recommendation mentioned above, a dispersal distance of 25km was used as a maximum distance between patches of the same landscape. The distance was chosen because it has been proposed by many scientists as a good compromise between short and long-distance dispersers (Botsford et al. 2001, Shanks et al. 2003, Palumbi 2004, Halpern et al. 2006).

b) Species specific approach: To illustrate a more realistic situation, another approach was also taken. Five species were chosen for the assessment. Based on information on their preferred habitats, sets of benthic marine landscape types were combined to form a clusters of potential habitats for each of the chosen species. The dispersal distance used in the analysis was based on the knowledge of the species' maximal ability to disperse. The selected species are widespread in the Baltic Sea, common, and represent different dispersal strategies. The species chosen, the landscapes combined and dispersal distances used to analyze connectivity from that species' "point of view" are presented in Table 11 below.

In both of these approaches, the level of connectivity was defined by classifying landscape patches of benthic marine landscapes on the basis of how many connections they have to their neighbours, independent of whether they were within the same MPA or different MPAs. Therefore, both within-site and between-site connectivity were considered in the assessment.

Table 10. Benthic marine landscapes used in the analysis of connectivity, their distribution and representation within SACs, within SACs + SPAs and within BSPAs.

Target of analysis	**Distribution of the landscape**	**Representation % SAC / SAC+SPA / BSPA**
Hard bottom, non-photic, 5-7.5 psu	Predominant in the Bothnian Sea and the Gulf of Finland.	8 / 9 / 12
Sand, euphotic, 7.5-11 psu	Coastal, in the northern Baltic Proper.	45 / 72 / 48
Sand, non-photic, 11-18 psu	Predominant in the southern Baltic Sea.	5 / 7 / 6
Mud, euphotic, 0-5 psu	In estuaries, coastal lagoons and in the Bothnian Bay.	19 / 30 / 24
Mud, non-photic, 18-30 psu	Predominant in the SW Baltic Sea.	6 / 8 / 1

Table 11. *Species selected for the analysis of connectivity at the marine landscape level and the substrates, salinity class and photic depth chosen as their potential habitats. The dispersal distances are estimates, based on genetic and behavioural studies.*

Species	Substrates	Salinity	Photic depth	Dispersal distance	Notes and references
Macoma baltica (Baltic tellin)	Sand and mud [1]	>5 psu	Non-photic and eu-photic	100km [2]	Tolerates salinity of 4 psu [3]. Distribution whole Baltic Sea, except the Bothnian Bay.
Psetta maxima (turbot) spawning and nursery grounds.	Bedrock, hard bottom complex and sand [4]	>5 psu	Eu-photic	25km [5]	Spawning and nursery grounds are not found north from the Finnish south coast.
Furcellaria lumbricalis (a red alga)	Bedrock and hard bottom complex	>5 psu	Eu-photic	25km [6]	Distribution whole Baltic Sea except the Bothnian Bay.
Idotea baltica (an isopod)	Bedrock and hard bottom complex	>5 psu	Eu-photic	25km [7]	Distribution whole Baltic Sea except the Bothnian Bay.
Fucus vesiculosus (Bladder wrack)	Bedrock and hard bottom complex	>5 psu	Eu-photic	1km[8]	Distribution whole Baltic Sea except the Bothnian Bay.

[1] MarLIN, [2] larval settling time 1-6 months, MarLIN, [3] Laine & Seppänen 2001, [4] Iglesias et al. 2003, Sparrevohn & Støttrup 2003, Stankus 2006, [5] based on genetical studies, Florin & Höglund 2006, [6] Fletcher & Callow 1992, Norton 1992, [7] based on measurements by Alexander & Chen 1990. [8] according to Gaylord et al. (2002) a fraction of algal propagules can drift distances of several kilometres

4.5.1 Methodology

As a first step, the generalized benthic marine landscape map was masked by SACs to create a layer presenting only those landscapes occurring within the SACs. The benthic marine landscape types chosen for the analysis (presented in Table 10) were then extracted one by one from the layer. In the species-specific approach, all landscape types relevant for that species (Table 11) were extracted simultaneously and reclassified to form one combined class. After the patches of a certain landscape type (or landscape types in the species-specific approach) were extracted, each landscape patch was given a unique individual code. For these landscape patches, a neighbourhood analysis was carried out. A 25km search radius for neighbours was used when applying the landscape approach and when applying the species specific approach, a specific distance for each species was used (Table 11). The method is illustrated in Figure 21.

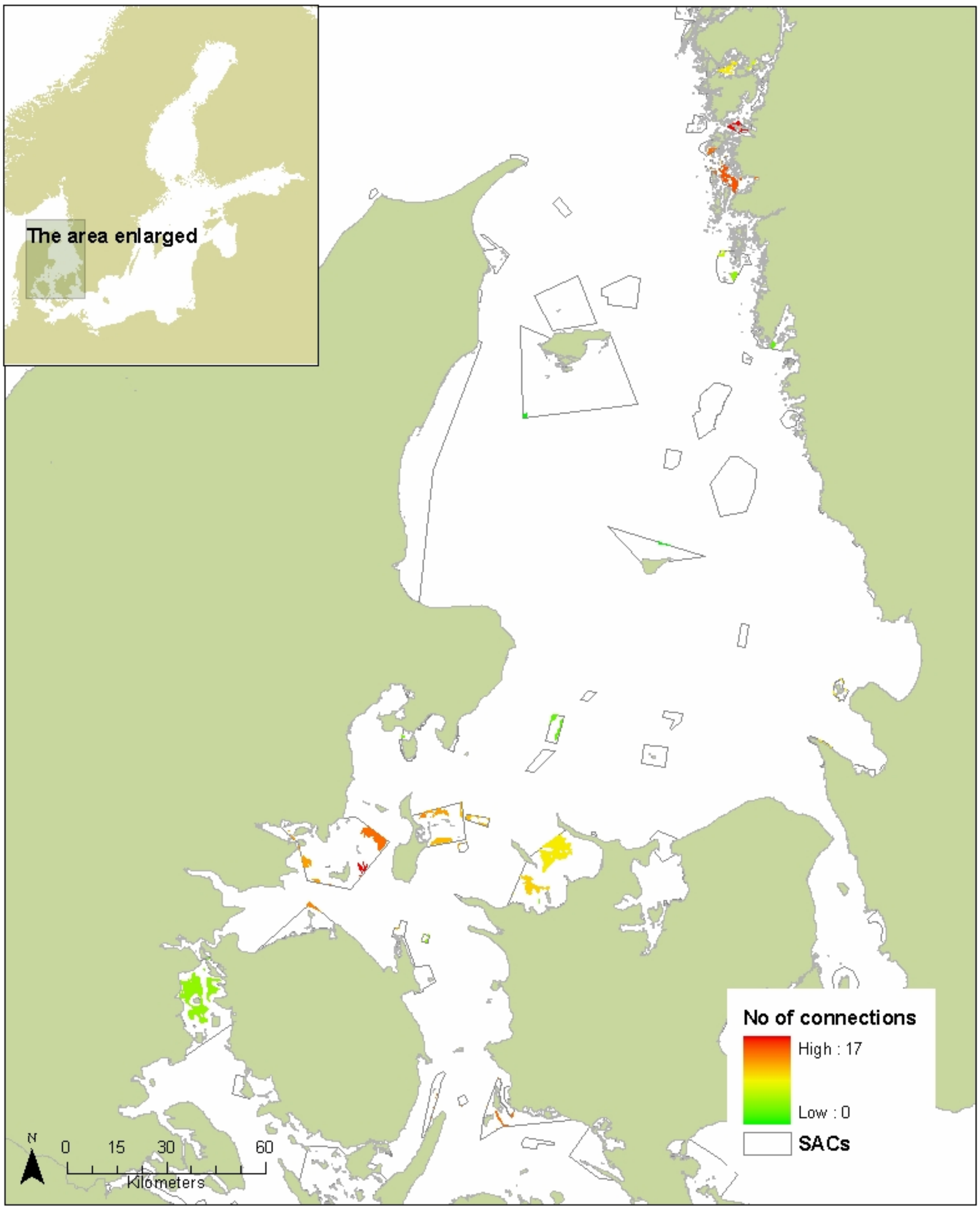


Figure 21. Number of connections for each patch of non-photic mud in 18-30psu salinity within SACs. The result has been achieved by neighbourhood analysis and it shows the number of similar landscape patches within 25km distance for each landscape patch. Green colour represents a low number of neighbours while orange and red represent a higher number of neighbours. Results are shown in the pie chart in Figure 23 E.

An additional approach was also used to visualize connectivity between landscapes. After the landscape / landscapes of interest were extracted and each patch had been given individual codes, the patches were expanded by half the dispersal distance in all directions. By doing this, all patches that were within the dispersal distance from each other were connected to each other to form clusters. All clusters were then given unique individual codes. The number of clusters and the number of patches within each of these clusters was then calculated. The method is illustrated in Figure 22. The same analyses were carried out also for SACs and SPAs together and separately for BSPAs.

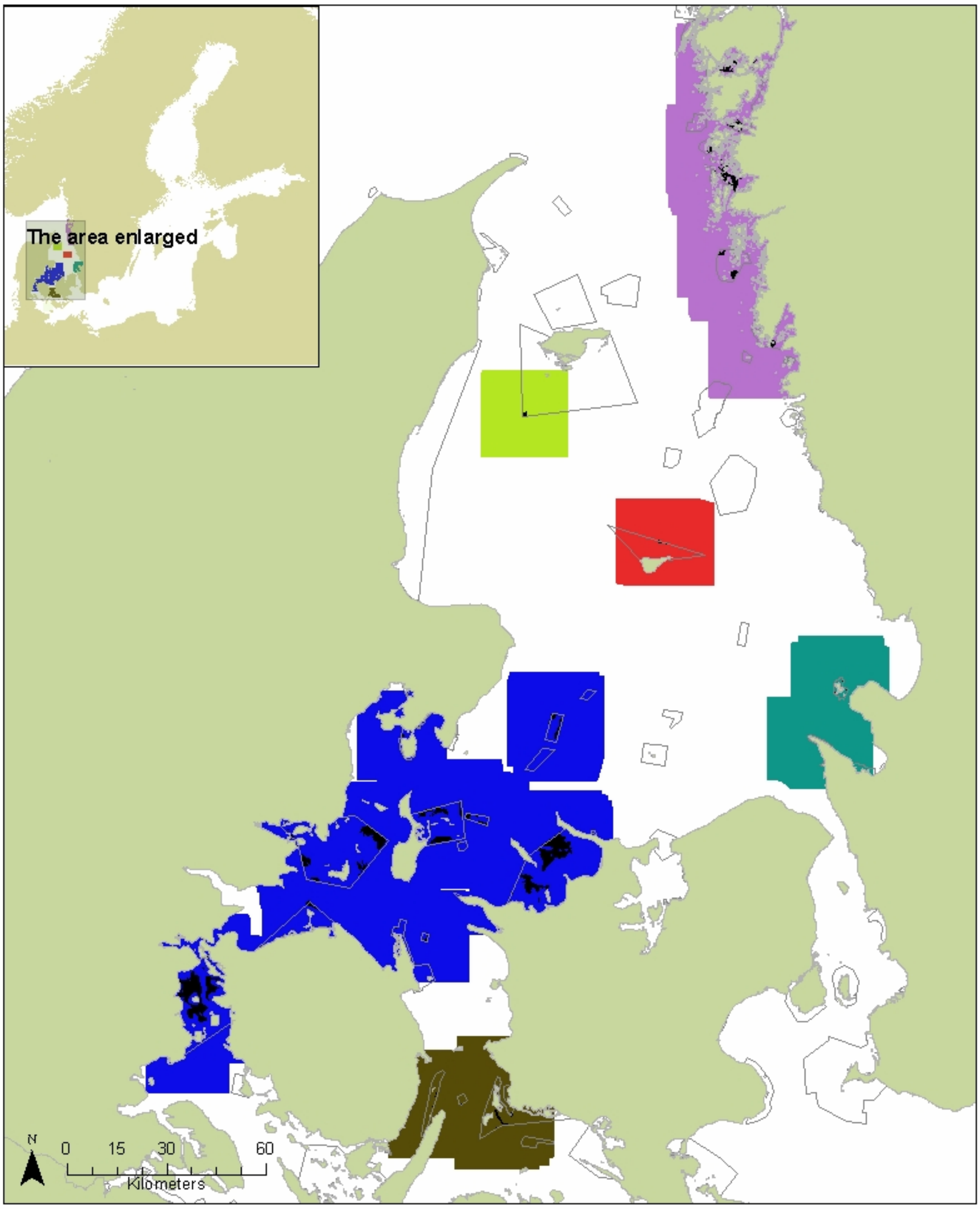


Figure 22. Clusters of non-photic mud in 18-30psu salinity occurring within SACs. The result has been achieved by expanding the landscape patches 12.5km in each direction. As a result, the landscape patches that are within 25km of each other form clusters. Different colours represent separate clusters (6) and the landscape patches themselves can be seen in black.

4.5.2 Results and discussion on the Natura 2000 network assessment

The "25km approach"

The five selected benthic marine landscapes showed relatively high numbers of connected patches within the Baltic Sea Natura 2000 network (Figure 23). With the theoretical fixed 25km dispersal distance, the majority of the chosen benthic marine landscapes had at least four connections to other protected patches. In most of the cases, the inclusion of SPAs to the analysis did not increase the connectivity of the landscapes within the network. The amount of protected patches (=replicates) increased, but the added patches were situated in areas where they did not contribute to the connectivity of the whole network. The extra protected patches, however, increased the representation and replication of the landscape. This result clearly shows the importance of locating the new protected areas in such a way that they also contribute to connectivity and create "stepping stones" for species.

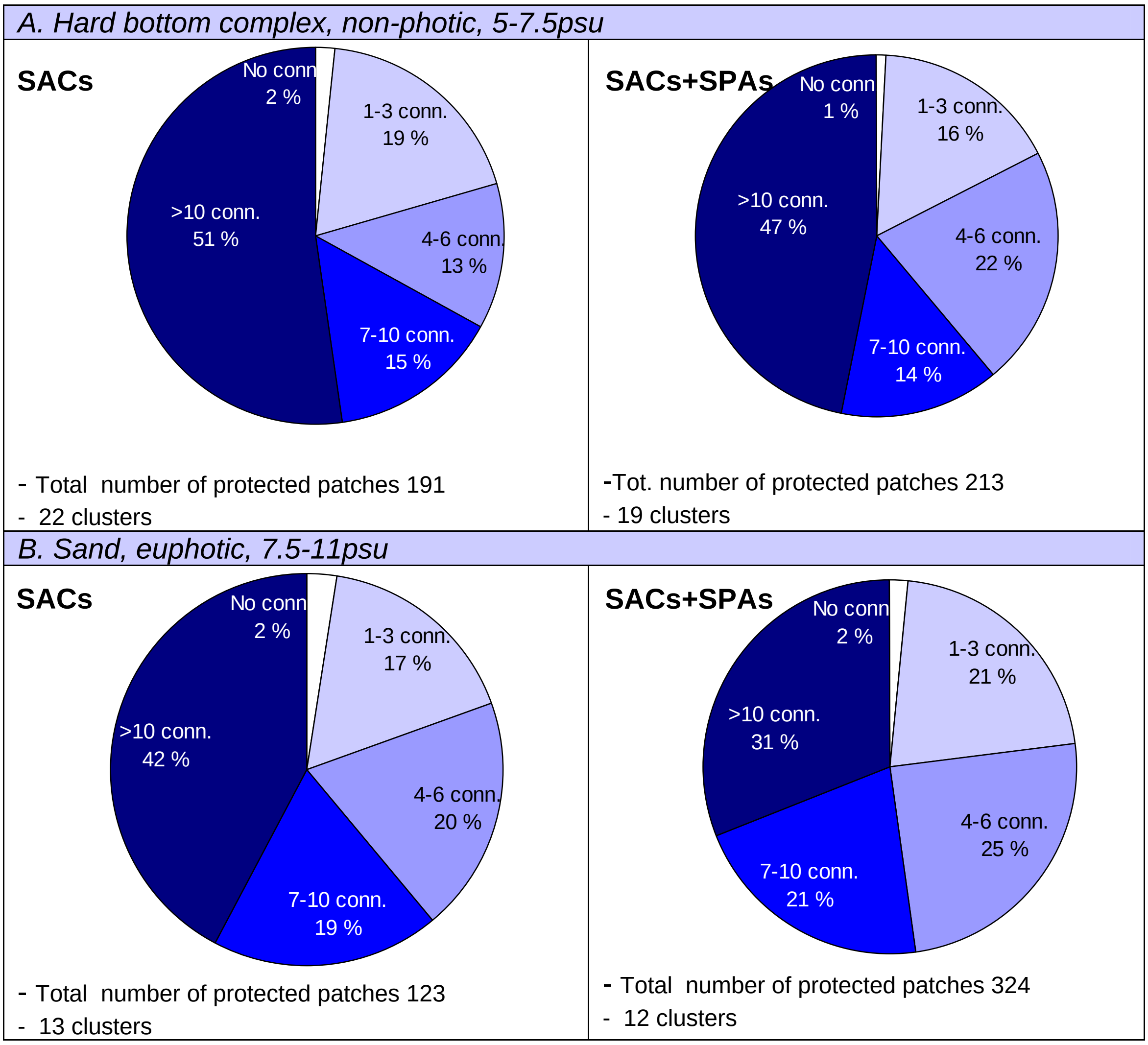
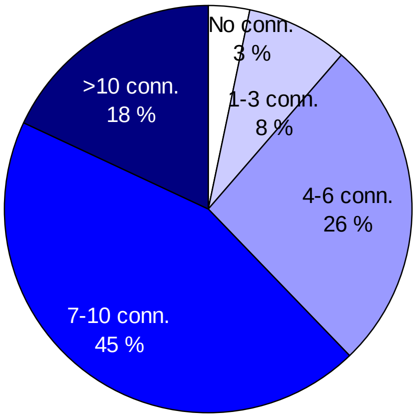


Figure 23. (continues on the next page) Connectivity assessment of selected benthic marine landscapes (A-E). The five categories represent the level of connectivity among the benthic marine landscape patches. (Conn. = number of connections between similar landscape patches). The connectivity among patches protected within SACs and within SACs and SPAs combined are presented in separate graphs. For clarification on clusters see Figure 22.

Figure 23 continues

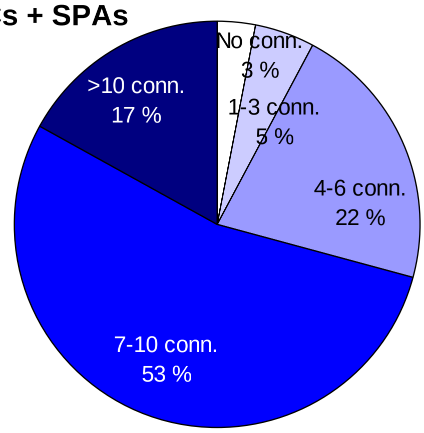
C. Sand, non-photic, 11-18psu

SACs



- Total number of protected patches 61
- 5 clusters

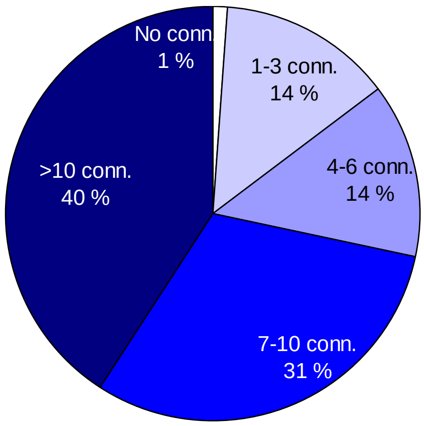
SACs + SPAs



- Total number of protected patches 65
- 5 clusters

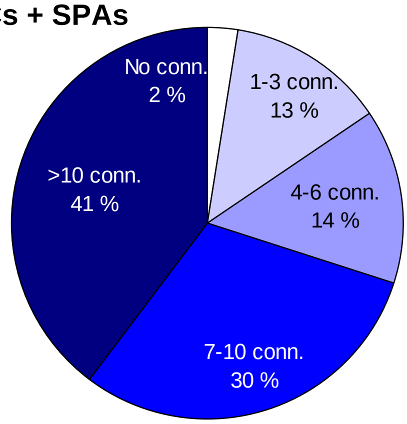
D.. Mud, euphotic, 0-5psu

SACs



- Total number of protected patches 81
- 8 clusters

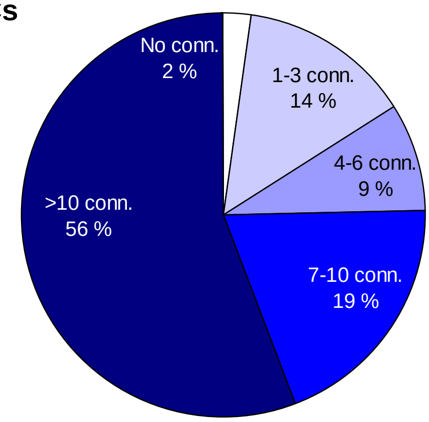
SACs + SPAs



- Total number of protected patches 83
- 9 clusters

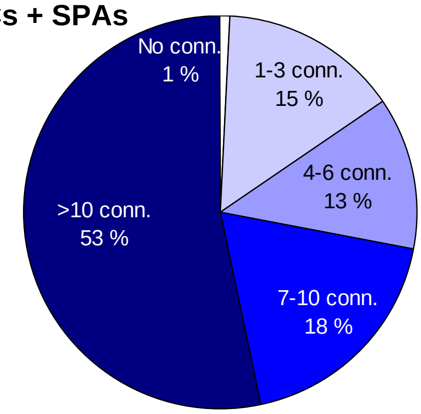
E. Mud, non-photic, 18-30psu

SACs



- Total number of protected patches 93
- 7 clusters

SACs + SPAs



- Total number of protected patches 103
- 7 clusters

The distribution of the connected landscape patches occurring within Natura 2000 network and the size and the number of clusters they form was also evaluated. The number of clusters formed by the protected landscape patches (in SACs and in SACs and SPAs combined) is presented in figure 23. The distribution and sizes of the clusters formed by patches occurring within SACs are shown on maps in Figures 1 to 4 in Annex 8.4. and the map of *non-photic mud in 18-30psu salinity* within SACs is shown in the example in Figure 22 above. Generally, the clusters vary a lot in size as some of them are formed by only a few patches and some included tens or even hundreds of landscape patches. It also became evident that all clusters are concentrated along the coastlines of the Baltic Sea, which results from the gaps in representation within the SAC and SPA networks in the offshore areas. These gaps limit connectivity of the landscapes within the Natura 2000 network across the offshore areas of the Baltic Sea.

Even if the overall number of connections between landscape patches was often found to be high, many protected patches are within the same MPA or concentrated in clusters close to each other, sometimes resulting in low between-site/between-cluster connectivity on a broader geographical scale (see figures 1-4 in Annex 8.4). Although the importance of large scale dispersal varies between species, between-site/between-cluster connectivity would be important to consider when designing new sites to the network in order to secure dispersal and genetic exchange over large areas.

Species-specific approach

The species-specific approach, performed for landscapes suitable for Baltic telling (*Macoma baltica*), using 100km dispersal distance showed relatively high connectivity as almost 100% of the patches have over 10 connections to neighbouring patches (Figure 24A). Also, by using the 100km dispersal distance, the connected landscape patches suitable for *Macoma* form only one large cluster (See Figure 5 in Annex 8.4). This is not surprising as *Macoma* is not only an efficient disperser, but also a very widespread species in the Baltic Sea occurring both in muddy and in sandy substrates, especially the latter being very common in the Baltic Sea. This assessment, however, did not take into account water flows, which are very important for planktonic dispersal (Roberts 1997, Cowen et al. 2000, 2006). Therefore, the connectivity for *Macoma* may be restricted to only certain directions according to local water currents.

The connectivity of landscapes suitable for turbot (*Psetta maxima*) (Table 11) is also relatively high as 83% of the patches have more than ten connections to neighbouring patches (Figure 24B). Some of the clusters formed by connected patches are rather large, therefore securing dispersal over relatively long distances, but on the other hand some of the clusters are small and isolated (Figure 6 in Annex 8.4). Therefore there is still a lot of potential for improving connectivity over long distances. The inclusion of SPAs to the network further increased connectivity. The number of protected patches increased by almost 200 hundred patches and the number of connected clusters decreased at the same time by 10, indicating better connectivity.

The landscape types and dispersal distances used for the red alga *Furcellaria lumbricalis* and the isopod *Idotea baltica* were exactly the same (Table 11) and therefore the results of the same connectivity analysis applies for both species. The result shows that connectivity of suitable benthic landscapes for *F.lumbricalis* and *I.baltica* is relatively high; over 90% of the patches have at least four other suitable patches for these species within a

25km distance (Figure 24C). Again, some of the clusters formed by connected patches are rather large, securing dispersal over relatively long distances, but on the other hand some of the clusters are small and isolated (Figure 7 in Annex 8.4). As these species occur only in the euphotic landscapes where most of the SPAs are, the inclusion of SPAs to the SAC network further enhanced connectivity. The decrease in the number of clusters due to the addition of SPAs also indicates enhanced connectivity among landscape patches.

On contrast, when assessing connectivity using a short distance disperser, *Fucus vesiculosus*, connectivity was found to be very poor with few connections and many isolated clusters (Figure 24D for clusters formed see also Figure 8 in Annex 8.4). This is rather worrying, as even a dispersal of 1km can be considered very long for *Fucus vesiculosus,* as this kind of "long distance" dispersal only happens via drafting individuals. Usually, the dispersal of *Fucus* is limited to only few or tens of meters (Serrao et al. 1996, Korpinen et al. 2007). The result is also interesting when keeping in mind that *Fucus vesiculosus* is a species that inhabits shallow littoral zones of the coastal areas, where most of the SACs are found, and that it is a key species in many of the Natura 2000 habitats that the SAC network actually aims to protect (e.g. *Reefs*, the underwater parts of the *Boreal Baltic islets and small islands*, as well as underwater parts of *Esker islands*). The inclusion of SPAs into the analysis increased connectivity of the protected landscape patches suitable for *Fucus*, but still the majority of the patches were still poorly connected to each other. This can clearly be seen in the huge increase in the number of connected clusters (Figure 24D). The number of protected patches increased, but mostly in the areas where they formed new isolated clusters.

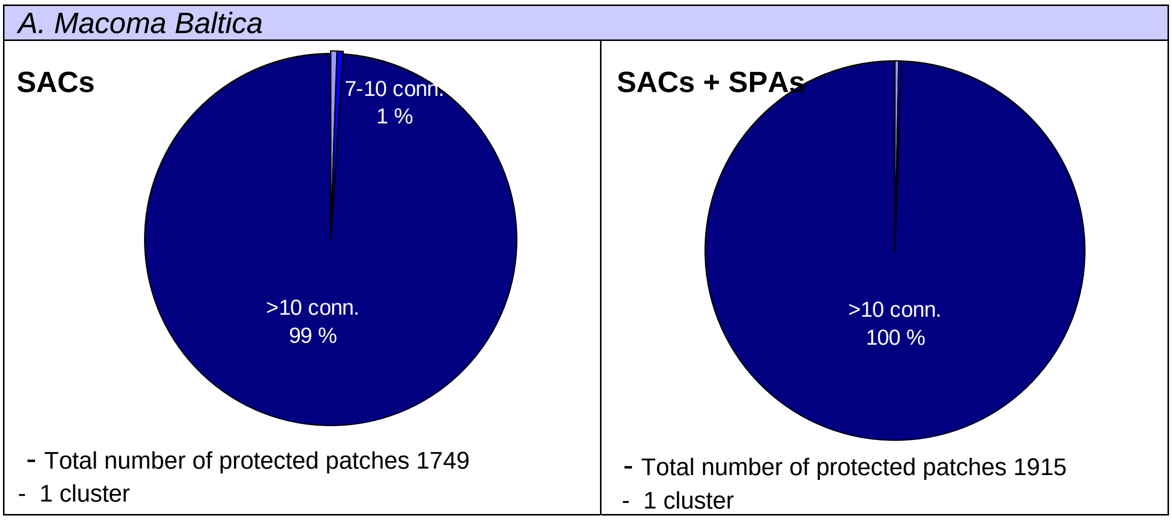
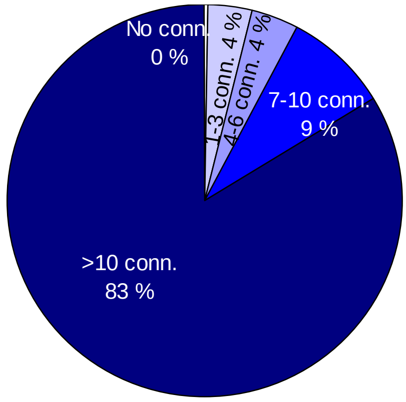


Figure 24. (continues on the next page) Connectivity assessment for a) Macoma baltica, b) Psetta maxima, c) Furcellaria lumbricalis and Idotea baltica and d) Fucus vesiculosus. The five categories represent the level of connectivity among benthic marine landscape patches these species use as their habitats. (Conn. = connections to other suitable patches for species in question). The connectivity among patches protected within SACs within SACs and SPAs combined are presented in separate graphs. For clarification on clusters see figure 22.

Figure 24 continues

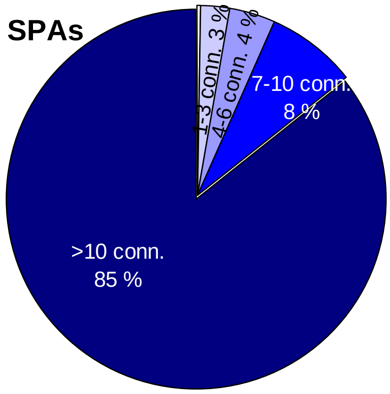
B. Psetta maxima

SACs



- Total number of protected patches 1474
- 25 clusters

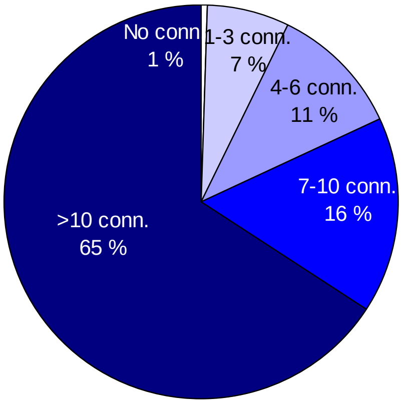
SACs + SPAs



- Total number of protected patches 1675
- 15 clusters

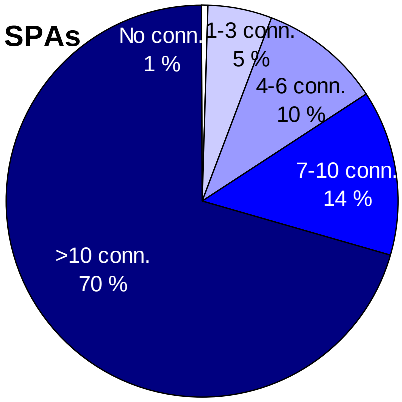
C. Furcellaria lumbricalis / Idotea baltica

SACs



- Total number of protected patches 972
- 28 clusters

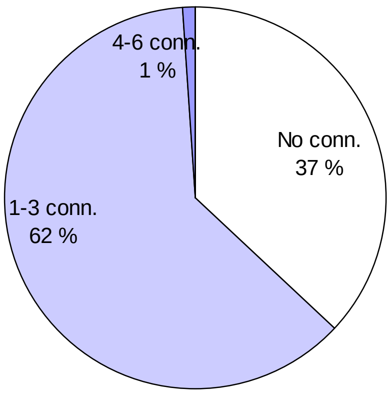
SACs + SPAs



- Total number of protected patches 1131
- 21 clusters

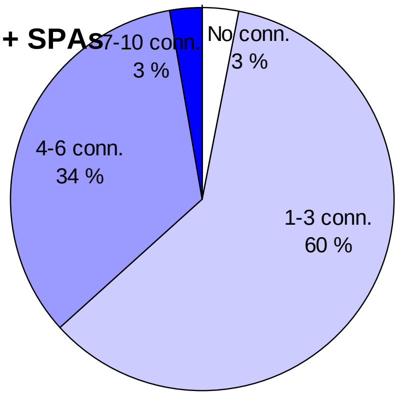
D. Fucus vesiculosus

SACs



- Total number of protected patches 972
- 491 clusters

SACs + SPAs



- Total number of protected patches 5083
- 3845 clusters

These results clearly imply that when considering widespread species with long dispersal distances, the connectivity of the current Natura 2000 network is generally relatively high, especially in the coastal areas where most of the sites are situated. It must be kept in mind, however, that due to gaps in the network in the offshore areas, the species inhabiting only deeper offshore areas are currently not protected within the network and therefore no connectivity between protected patches can occur in these areas.

Furthermore, when it comes to species with low dispersal abilities, the network is clearly not sufficient. The *Fucus* example showed this is also true in the coastal areas where most of the SACs occur and even for a key species in many of the Natura 2000 habitats that the SAC network aims to protect. The designation of SPAs as SACs would not significantly improve the situation, at least in the case of *Fucus vesiculosus*. As coastal areas are generally dominated by smaller scale processes and host a lot of species with short dispersal distances, the network of sites should either be more dense, the sites should be larger (to host more separate patches of fragmented habitats), or the sites should be placed more carefully, in a way that they would increase connectivity of the short distance dispersers.

Important considerations

When interpreting the results of this connectivity assessment, it should be kept in mind that both the selected landscapes and the selected species were wide-spread and common in the Baltic Sea and therefore likely to show rather good connectivity. This may not be the case, however, if connectivity was tested on more rare landscapes or landscapes occurring mainly in the deeper offshore areas of the Baltic Sea, where severe gaps in representation have been shown to occur (see chapter 4.3). Also, using more species that lack a pelagic phase in their life history or otherwise have low dispersal abilities would indicate much lower connectivity of the current MPA networks in the Baltic Sea.

As mentioned in chapter 4.4., the natural patchiness of the landscapes in the Baltic Sea causes high replication of the patches both inside and outside MPAs, which in turn results in high potential connectivity. Some of these landscape patches, however, may not be adequate e.g. in size or in quality, to be considered as suitable replicates of that landscape. In this assessment 24 hectares was set as a minimum size for a protected patch to be included. The quality of the sites was not considered.

It is also very important to keep in mind that the analysis presented here includes both within-site and between-site connectivity. When comparing the numbers of protected landscape patches and the numbers of MPAs hosting these patches in tables 8 and 9 on replication (Chapter 4.4), it becomes obvious that many of the protected patches actually occur within the same sites. Therefore, within-site connectivity plays a major role in the results. Both within and between-site connectivity, however, are important for a network to be considered well connected. Obviously, the potential for the large-scale between-site dispersal depends on the distribution of the landscape patches and its importance varies between species. The within-site connectivity could be disregarded by grouping all patches of a particular landscape within the same site to form one replicate. The problems arising when using this approach (and other problems in defining a replicate) are discussed in chapter 4.4.

As mentioned earlier, this connectivity assessment only takes into account distance between protected landscape patches and does not take into account currents or other water movements aiding dispersal or migration of species between landscape patches. This is a major disadvantage of the assessment that probably leads to an overestimation of the connectivity. Another important aspect not considered in the assessment is the inclusion of more detailed information on the species' life histories e.g. concerning pelagic phases or phases of active migration. In order to do this, more detailed information on the water movements as well as species distribution and their life histories are needed. As the aim of this assessment was to get a general overview of connectivity of the Baltic Sea MPA networks and to take a first step towards further assessments, this kind of a detailed or a more species specific approach was not possible. An example, however, of using current models in assessing connectivity is presented in chapter 4.5.4. as a case study.

Connectivity results in summary (Natura 2000):

1. This assessment indicates that the Natura 2000 network supports relatively high connectivity when it comes to species with long dispersal distances occurring in the coastal areas of the Baltic Sea.

2. Due to gaps in representation in the offshore areas, the network does not sufficiently support connectivity of the species occurring in these areas.

3. The assessment also indicates that the Natura 2000 network currently does not support connectivity of short distance dispersers, even in the coastal areas or for key species inhabiting Natura 2000 habitats.

4. The designation of SPAs as SACs would not significantly improve connectivity of the Natura 2000 network.

5. In order to improve connectivity of the Natura 2000 network;

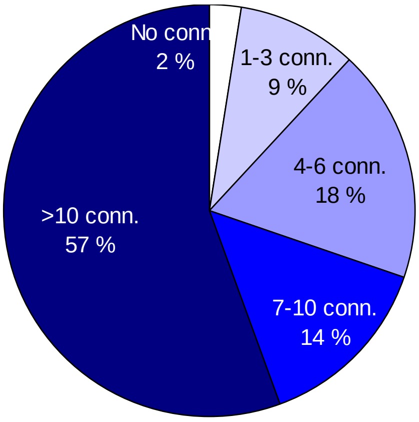
- More sites should be designated in the offshore areas.
- More large sites (or smaller sites placed carefully to support connectivity) should be designated in the coastal areas to support short-distance dispersal (also see chapter 4.5.3)

4.5.3 Results and discussion on the BSPA network assessment

The connectivity assessment of the BSPA network generally showed rather similar results to the assessment on the Natura 2000 network (see chapter 4.5.2). While keeping in mind the commonness and the wide range of the landscapes and species used in the assessment, it is important to remember, that currently not all designated BSPAs have legal protection status. Therefore, the results can indicate what the level of connectivity of the network *would have*, if all sites had legal protection.

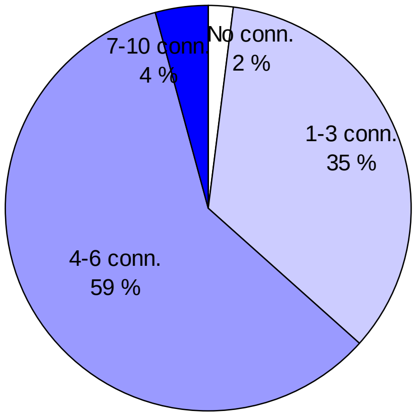
Connectivity of the benthic marine landscape patches within the BSPA network (notified, designated and proposed sites) was generally found to be relatively high when using 25km dispersal distance (Figure 25). Most landscapes have a high number of connections and relatively few clusters. Of the five selected landscapes, only one, *non-photic mud in 18-30 psu*, shows relatively poor connectivity as 64% of the patches has, at most, three connections to each other. This landscape has only 14 patches within BSPAs (of total 145 patches) and they form five separate clusters.

A. Hard bottom complex, non-photic, 5-7.5psu



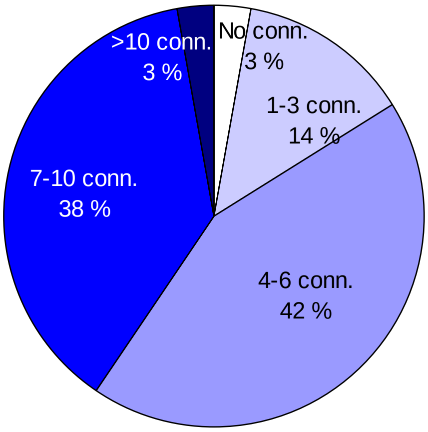
- Number of protected patches 169
- 17 Clusters

B. Sand, euphotic, 7.5-11psu



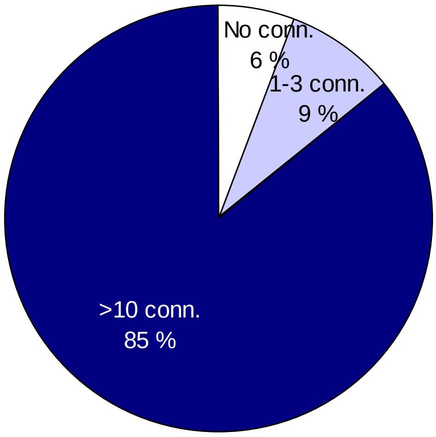
- Number of protected patches 49
- 9 Clusters

C. Sand, non-photic, 11-18psu



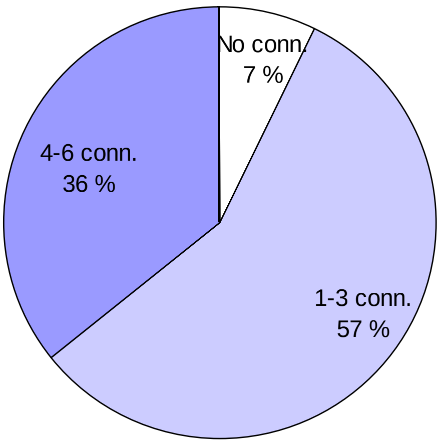
- Number of protected patches 37
- 4 Clusters

D. Mud, euphotic, 0-5psu



- Number of protected patches 35
- 4 Clusters

E. Mud, non-photic, 18-30psu



- Number of protected patches 14
- 5 Clusters

Figure 25. Connectivity of selected benthic marine landscapes within BSPAs. (Conn. = connections to similar patches). For clarification on clusters see Figure 22.

As in the Natura 2000 network assessment, the species-specific approach showed relatively high connectivity among landscape patches suitable for widespread species with relatively high dispersal abilities: Baltic telling (*Macoma baltica*), turbot (*Psetta maxima*), the red alga *Furcellaria lumbricalis* and the isopod *Idotea baltica* (Figure 26). The majority of the patches suitable for these species had more than ten connections to each other. In the case of species with dispersal distance of 25km, however, many of the clusters formed by connected patches were relatively isolated from each other due to relatively long gaps between the BSPAs in some areas. Therefore, high connectivity occurred mostly within sites and the between-site connectivity remained weak. In addition, as most of the BSPAs are situated in the coastal areas, it is clear that the connectivity is weak across the deeper offshore areas of the Baltic Sea and the network does not support good connectivity for the species inhabiting these areas.

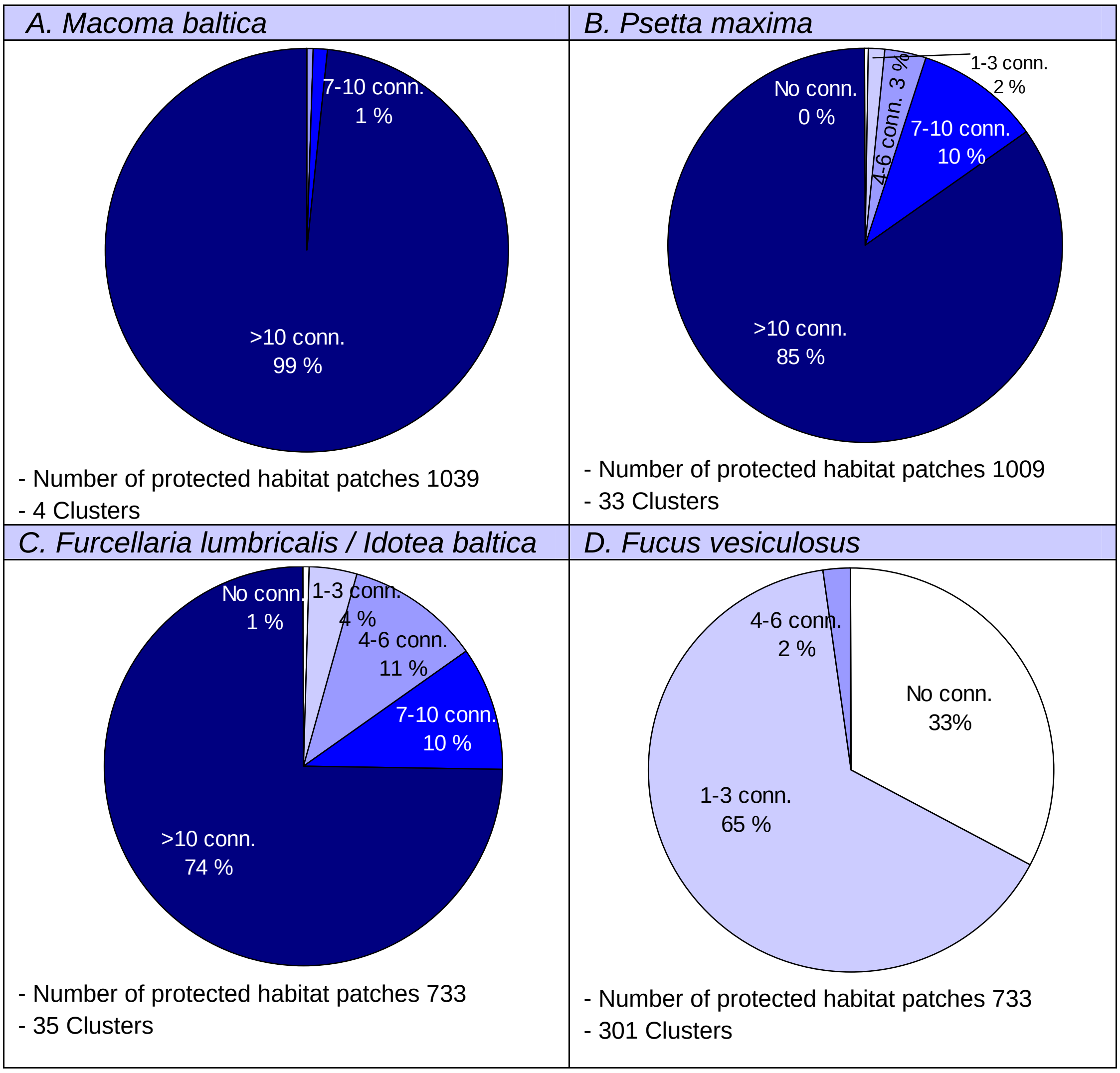


Figure 26. Connectivity of suitable habitat patches within BSPAs for a) Macoma baltica, b) Psetta Maxima, c) Furcellaria lumbricalis and Idotea baltica and d) Fucus vesiculosus. (Conn. = connections to other suitable patches for species in question). For clarification on clusters see Figure 22.

The assessment carried out on *Fucus vesiculosus* showed that most of the suitable patches that are protected had less than four connections to each other (Figure 26D) and they formed many isolated clusters. When looking closer at large BSPA sites where landscape suitable for *Fucus* were common, however, the landscapes suitable for *Fucus* forms rather large clusters indicating relatively good connectivity within the sites. As mentioned in chapter 4.2, small MPAs will only function if special attention has been given to securing connectivity between sites and the features they contain. For short distance dispersers that occur in fragmented habitats, securing connectivity is "easier" in larger sites, as one site covers many separate habitat patches and therefore also secures connectivity between the patches.

Connectivity results in summary (BSPA):

1. The assessment indicates that the BSPA network supports relatively good connectivity when it comes to species with long dispersal distances occurring in the coastal areas of the Baltic Sea.

2. Due to gaps in representation in the offshore areas, the network does not support connectivity of the species occurring in these areas.

3. The assessment also indicates that the BSPA network does currently not support connectivity of the short distance dispersers sufficiently, but some indications of relatively good within-site connectivity were found in larger sites.

4. In order to improve connectivity of the BSPA network;

- More sites should be designated, especially in the offshore areas but also in the coastal areas.

4.5.4 Case study on connectivity

Passive transport of pelagic life stages and the "upstream downstream" ordering of Natura 2000 areas in the Danish waters in Kattegat

A case study was done to demonstrate the importance of passive transport pathways of pelagic life stages of marine flora and fauna in the Danish waters of Kattegat (Bendtsen et al 2007). Two different tracer studies show the dispersal by currents (advection) and turbulent mixing (diffusion) of water masses for different parts of the Baltic Sea area. The first study includes a so-called “conservative tracer” suited for documenting long term transport. A conservative tracer has no decay and therefore its distribution is controlled solely by currents and mixing. The second study included a so-called “non conservative tracer” having a decay rate that represents the behaviour of a larva, a propagule or other kinds of biomass which are also controlled by biological processes, e.g. mortality. These studies simulate potential “blue corridors” between several locations in the Baltic Sea. Figure A shows two examples of non-conservative tracers spreading from Natura 2000 areas with reef habitats in Kattegat.

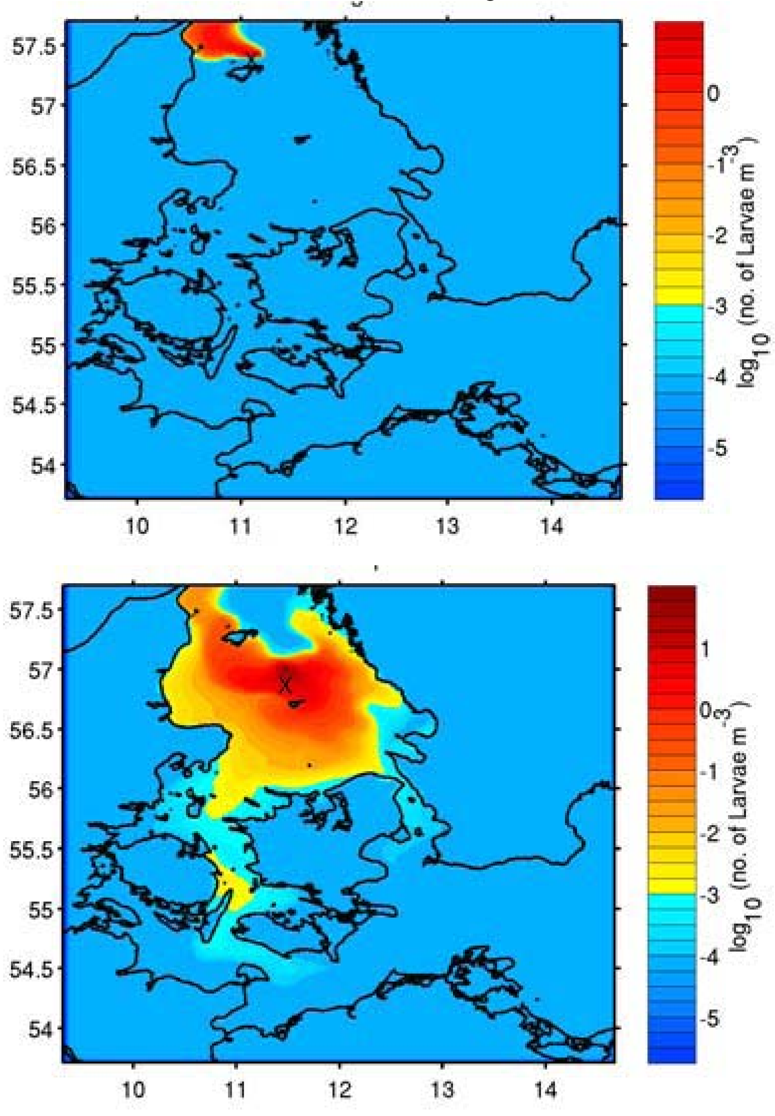


Figure A. Model results that show the mean concentration in July of non-conservative tracers in the model bottom layer. The tracer had continuously been released from 9 location marked with X throughout the water column during a 6-month period. Above Tønneberg Banke: 11° 16,26'E 57° 28,328'N, below Kim's Top 11° 35.42'E 57° 01'N (Bendtsen et al. 2007)

The attempt to quantify the role of blue corridors concerning passive dispersal using the tracer approach confirms that dispersal can in fact be a limiting factor concerning both the maintenance of populations at one given location and the exchange of individuals between locations. The modelling of tracers showed that internal recruitment at one given area varies considerably between source areas as tracers released from the two northern stations were diluted ten times more than in the central Kattegat. This means that a greater proportion of the dispersal units are potentially lost as they may spread over unsuitable areas.

Furthermore, this tracer study also shows that the relative role of a certain area as a source of pelagic larvae or propagules indeed varies and that the concept of ranking areas in "downstream" and "upstream" locations is possible and makes sense (Figure B).

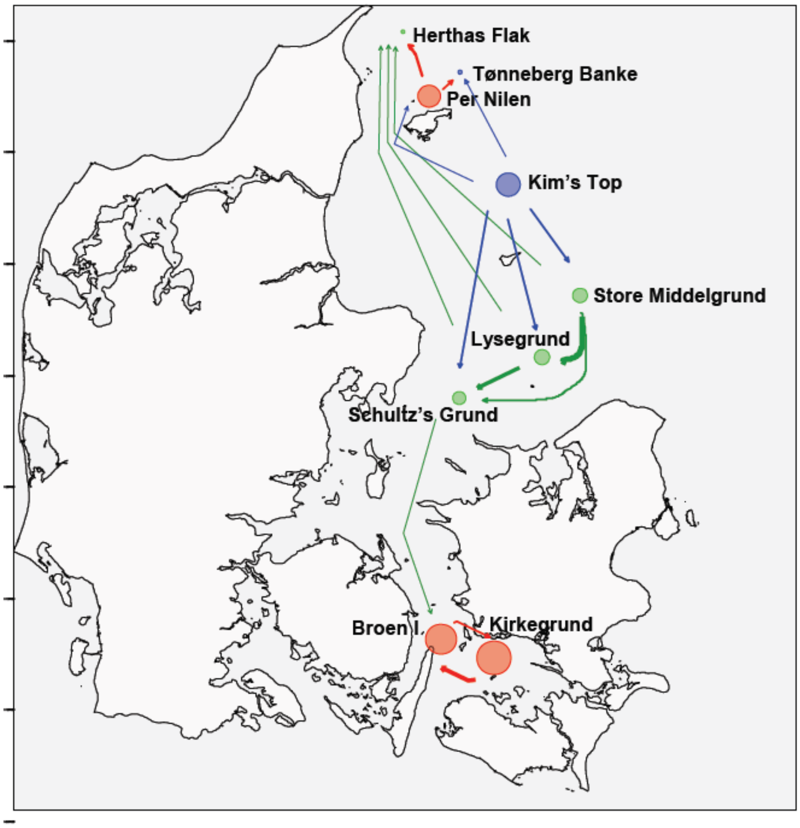


Figure B. Overall dispersal routes of tracers in the Kattegat and Belt Sea. Diameters of circles are scaled proportionally to average tracer concentration in the bottom layer. (Bendtsen et al. 2007)

In this example, the tracer study showed that the central part of Kattegat was the highest ranking area in the "upstream and downstream hierarchy" of the inner Danish waters (Kim's Top as the highest ranking area followed by Store Middelgrund) and thus an important donor area, whereas the northern Kattegat clearly was "downstream" area (Herthas Flak and Tønneberg Banke). This pattern actually conforms to the hypothesis that the species pool of soft-bottom invertebrates located in the central part of Kattegat exports larvae, propagules or other dispersal life stages to other areas, thereby help to maintain population and biodiversity in adjacent areas (Josefson & Hansen 2004).)

In the case of hard substrate communities associated with a more limited distribution of suitable substrate than the soft bottom communities, dispersal may be even more critical and the role of certain stone reef as stepping stones could be evaluated using the same tracer approach.

These examples assume one type of life cycle, including vertical distribution of dispersal units, a decay rate of 0.2 per day and settling behaviour limited to the bottom grid layer. The modelled period and settling time are also limited. Other approaches may result in different dispersal patterns.

A more general ranking of areas would require testing of many different dispersal strategies and extending the modelled period to a whole year. Running the model for several years characterized by different weather conditions would also be a major step forward.

4.6 Conclusions and recommendations

The ecological coherence of the networks of marine protected areas (Natura 2000 and Baltic Sea Protected Areas) in the Baltic Sea was assessed by analysing adequacy in terms of MPA size, geographical distribution of the sites, representation of marine landscapes within the sites in addition to replication and connectivity of protected benthic marine landscape patches. The assessment was done at the Baltic Sea scale, whereas some criteria were investigated within six sub-regions and country by country.

4.6.1 Conclusions - Ecological coherence of Natura 2000 network

The size distribution of Natura 2000 sites indicates that the network is **biased towards small sites**. The network of Special Areas of Conservation (SACs) currently consists of many small sites; more than 50% of the sites are less than 100ha in size and only 7% are more than 10 000ha in size. At this stage, the network of SACs is not sufficient with regard to MPA size. If the protective measures of the Habitats Directive also covered the Special Protected Areas (SPAs), the situation would be improved only slightly, as the inclusion of the SPAs to the analysis increased the number of sites in all the size classes. In order to be adequate, the Natura 2000 network should have a higher proportion of larger sites.

Based on the assessment, it can be concluded that the Natura 2000 network is **not representative with respect to its geographical distribution**. The network covers less than 20% of each of the sub-regions. The sub-regions with low salinity have the least representation i.e. the Bothnian Sea and the Bothnian Bay. The total Natura 2000 coverage in these regions is as low as 2%. Moreover, the geographical distribution of SACs is biased towards shallow coastal areas/territorial waters (11% coverage) whereas only a few SACs have been designated in the exclusive economic zone (3% coverage). Moreover, the proportionate coverage of sites differs considerably between the Member States. Germany is the only country with a designated area covering over 20% of their waters. Germany is also the only Member State where the coverage of sites in territorial waters and the exclusive economic zone is more or less equal.

Furthermore, it can be concluded that the Natura 2000 network is **not representative with respect to representation of the 60 benthic marine landscapes** in the region. Less than one third of the benthic marine landscapes are found in quantities over 20% within designated SACs and thereby as many as two thirds are found in quantities under 20%. The least represented landscapes are mostly in the non-photic zone and the better represented landscapes are mainly located in shallow waters regardless of bottom substrate or salinity. The Baltic Sea, however, comprises mostly deep non-photic areas.

The dominant bottom substrates in the Baltic Sea are mud and hard clay, covering approximately two thirds of the seafloor. Not surprisingly, protected substrate types with the lowest proportionate protection are mud, hard clay and bedrock. Benthic marine landscapes dominated by sand and hard bottom complex (stones and boulders) are better represented. These landscapes meet the recommended minimum 20% representation level, at least in the shallow waters.

Including the SPAs in the SAC network does not remarkably improve the total geographical coverage of sites in the Baltic Sea. The coverage in some countries, however, both nearshore and offshore, is slightly improved (primarily in Denmark, Estonia, Germany and Poland). Representation of some benthic marine landscape types is slightly improved, mostly in already well represented landscapes such as shallow sand and hard bottom areas. In general the designation of SPAs as SACs would not significantly increase the representation of the Natura 2000 network.

Clearly, many benthic marine landscapes are insufficiently represented in the current Natura 2000 network. The need to increase representation is most obvious in landscapes in the non-photic zone and in the landscapes dominated by hard clay and mud. It may also be questioned, however, whether protecting 20% of a common landscape is necessary and/or whether even larger proportions of rare or threatened landscapes are necessary. In addition, benthic marine landscapes in low salinity regions generally need a better representation in the Natura 2000 network.

Adequate representation of all benthic marine landscapes alone is not enough to form an ecologically coherent MPA network. Networks of protected landscape patches (replicates) connected to each other, both within and between protected sites, are essential to support viable populations of species. According to the assessment, **the number of replicates of most benthic marine landscapes is relatively high** but in many cases, the replicates do not cover whole landscape patches. Also, for some landscapes most replicates are located within only a few MPAs which can be regarded as a shortcoming of the network as the replicates should ideally cover the whole range of the features the network is aiming to protect. The number of replicates needed, however, and the minimum size for a landscape patch to be considered a replicate are also strongly dependent on the species characteristics. Therefore, no specific number for an adequate amount of replicates was possible to set at marine landscape level. Also the 24 hectare minimum size used in this assessment was only based on the resolution of the maps, not on the requirements of the species. The assessment, however, still gives a general overview of the replication of different landscapes in the Baltic Sea. It can be concluded that many of the landscapes have tens or hundreds of separate patches within the Natura 2000 network but it is not certain whether these patches are large enough to support viable populations of species or whether there is enough of them to support connectivity of the species occurring in these patches. In particular, the replication assessment showed that more effort is especially needed to increase the replication of hard clay bottoms.

Although some of the protected replicates of a landscape should be far enough from other replicates to give insurance against catastrophic events, in general the patches should be close enough to allow species to migrate / disperse among them. Within network connectivity of the benthic marine landscape patches was assessed for five selected landscape types and five species. In the former case, a 25km theoretical distance was used to illustrate dispersal / migration of species, and in the species-specific case, science-based distances and landscape types were chosen for the assessment. **The assessment indicates that for common and widespread species with dispersal distances of 25-100km, the Natura 2000 supports relatively high connectivity.** We may not be certain, however, that all replicates included in the assessment are large enough to support viable populations of species and therefore the results in this report may be an overestimation of the level of connectivity. In addition, there is often less connectivity on a broader scale as the clusters formed by connected patches are relatively isolated from each other. Therefore, the network is not sufficient in securing dispersal over larger areas. The assessment also shows that the areas of good connectivity are concentrated in the coastal areas, which results from gaps in representation of the conservation features in the network in the offshore areas. Therefore, **the network does not support connectivity of species only inhabiting deeper offshore areas.**

The assessment also indicates that **the Natura 2000 network does not currently support connectivity of short-distance dispersers**. When assessing connectivity using a 1km dispersal distance and landscapes suitable for *Fucus vesiculosus*, connectivity of the landscapes was found to be poor. This result is worrying, especially when keeping in mind that *Fucus vesiculosus* is a species that inhabits shallow littoral zones of the coastal areas, where most of the SACs are found, and that it is a key species in many of the Natura 2000 habitats that the network is aims to protect. The inclusion of SPAs in the network enhanced connectivity only slightly.

In conclusion, the results show that the current Natura 2000 network supports relatively adequate connectivity when considering wide-ranging long-distance dispersers in the near-shore areas, but is inadequate when it comes to short-distance dispersers and species inhabiting offshore areas. Even for long-distance dispersers, the between-site connectivity should be improved to secure dispersal over larger areas.

4.6.2 Conclusions - Ecological coherence of Baltic Sea Protected Areas

In contrast to the Natura 2000 network, individual BSPAs are rather large, the majority of the sites belonging to the size class 10 000-100 000 ha. Therefore, **in terms of MPA size, the BSPA network can be considered adequate**. Other aspects of adequacy, however, such as quality, shape, or the protection status of the sites, were not considered in this assessment. In addition, since many BSPAs included in this analysis are only proposed and not designated, the result is an overestimation of the adequacy of existing BSPAs.

The BSPA network is not representative with respect to geographical distribution of sites. The network covers less than 20% of all the large sub-regions. In the 18 smaller HELCOM sub-regions, the representation varied from 2 to 40%. Furthermore, the geographical distribution of sites is heavily biased towards coastal areas/territorial waters. The territorial waters have a 20% coverage of sites, whereas the exclusive economic zone only has a 2% coverage. There is also a large difference between HELCOM Contracting Parties with regard to proportionate coverage of designated and proposed sites. Germany is the only country with designated and proposed area covering more than 20%.

The BSPA network is not representative of the benthic marine landscapes, as many landscapes are insufficiently represented. The need to increase representation is, however, most obvious in landscapes in the deeper non-photic zone and in landscapes dominated by mud and hard clay. Representation is much higher in shallow water and in landscapes dominated by sand, bedrock and hard bottom complex.

Replication of the benthic marine landscape patches within the BSPA network is not as high as in the Natura 2000 network. Several landscape types have less than ten replicates within the network. Replication was found to be poorest in the bedrock and hard clay bottoms in mid and high-salinity regions. The problems in defining adequate size for a patch to be considered a replicate and defining the adequate amount of replicates at marine landscape level, that also have implications on the results of the BSPA network assessment, are discussed in chapter 4.6.1.

As in the Natura 2000 network, the **connectivity assessment of the BSPA network showed relatively high connectivity among landscape patches suitable for wide-spread species with relatively high dispersal abilities.** As the number of replicates was lower within the BSPA network, however, the connectivity values are also somewhat lower than within the Natura 2000 network. The non-photic mud in 18-30psu salinity especially, shows rather poor connectivity. Due to long distances between individual BSPAs, most of the connectivity occurs within sites and gaps in the between-site connectivity were found. Furthermore, as most of the BSPAs are situated in the coastal areas, it is clear that **the network does not support good connectivity of the species inhabiting only deeper offshore areas** of the Baltic Sea.

The assessment carried out on *Fucus vesiculosus* using 1km dispersal distance indicates that **the BSPA network does currently not support sufficient connectivity of the short-distance dispersers**. The larger sites, however, seemed to support relatively good within-site connectivity.

4.6.3 Recommendations

Recommendations to improve the current Baltic Sea MPA networks

The Baltic Sea countries are obliged by many international and regional agreements and conventions, as well as by EU law, to establish an ecologically coherent network of marine protected areas. To fulfil these obligations, the countries have established networks of protected areas in the Baltic Sea, i.e. the Natura 2000 network and the BSPA network. In order to be ecologically coherent, however, both of these networks have many gaps yet to fill, as shown by this preliminary assessment.

The most obvious gaps in representation of both networks are 1) inadequate protection of deeper offshore areas in the EEZs (except for Germany), 2) inadequate protection of muddy and hard clay bottoms that are very typical in the Baltic Sea and 3) inadequate protection of the low salinity areas in the Gulf of Bothnia. Therefore, in order to reach ecological coherence of the Baltic Sea MPA network, the Baltic Sea countries **should particularly designate sites in the deeper offshore areas, especially where mud and hard clay are found. Also, more sites are needed in the low salinity areas of Gulf of Bothnia.** It was also found that in general the Natura 2000 sites are too small to be considered adequate to protect marine biodiversity and therefore the countries **should designate more large sites** in the network. Designation of large sites would most likely also enhance within-site connectivity of the short distance dispersers, which was also recognized as a clear shortcoming of the current network.

The strengths and weaknesses of the current Baltic Sea MPA networks reflect, at least to some extent, the aims and the guidelines set in the "driving forces" for their designation i.e. the Habitats Directive and the HELCOM Recommendation 15/5 and the guidelines set by HELCOM (HELCOM 2003). For example, HELCOM has clear guidelines on the sizes of the BSPA sites and as a result, most of the sites are larger than the recommended size. On the other hand, the Habitats Directive aims to protect specific habitats and species listed in the Annexes of the Directive, and as a result, the site designation has been biased towards areas where these habitats and species occur. The majority of the marine habitat types listed in the Annex I of the Directive are coastal habitats, whereas very few habitats in the offshore deeper areas of the Baltic Sea are included. This can clearly be seen in the results: the deep muddy and hard clay areas remain unprotected. Several scientific recommendations, however, state that in order to reach ecological coherence of the MPA network, all features occurring in the area should be adequately represented (e.g. to at least 20%), not just some of them (Chiappone et al. 2000, Day & Roff 2000, Airamé et al. 2003, Roberts et al. 2003). As long as the Habitats Directive does not include all the habitats occurring in the region, it does not enable the establishment of an ecologically coherent network of marine protected areas. If a truly coherent network is to be established under Natura 2000, more habitats need to be included in the current Directive as well as guidelines for the establishment of larger sites.

Recommendations on how to improve the assessment

The present assessment of ecological coherence of the MPA networks is a first attempt in the Baltic Sea region and its results should be evaluated as a general overview and a first step towards further assessments. The large scale of the assessment and the coarse resolution of the datasets used should be kept in mind when interpreting the results, as any assessment is as good as its background data. It has shown, however, that it is possible to regionally assess ecological coherence of the Baltic Sea MPA networks. As species are not aware of political boundaries, the protection of the Baltic Sea biodiversity is a joint responsibility for all countries and a regional approach to assessing the MPA networks is important.

The methods used in this assessment are relatively simple and straightforward. As long as the gaps in the network are obvious, however, there is no need for very sophisticated methods. The assessment should be carried out repeatedly in order to follow progress in the implementation of the agreed conventions and the Habitats Directive. When the network improves and the gaps get less obvious, the assessment tools also have to be improved.

When evaluating ecological coherence of the MPA networks at a large scale, such as the Baltic Sea region, the use of proxies for the biological communities, i.e. biologically relevant geophysical parameters and marine landscape maps derived by combining them, can be considered a relatively suitable approach. In this kind of an approach, however, a lot of generalisations are necessary and might reduce the biological relevance of the assessment. Simplifications, however, can also be useful in keeping the assessment of this scale understandable and within a reasonable computing timeframe (as datasets can be large).

The analysis needs to be continuously improved when more knowledge and more data become available. The marine landscape maps used in this assessment were derived by incorporating only some of the most important geophysical features defining biological communities. There are also other biologically important geophysical parameters determining the distribution of species, such as wave exposure, depth or oxygen level which could also be used in future assessments. The choice of parameters is, of course, dependent on the specific needs and aims of the assessment. We acknowledge that several important aspects that have implications on the ecological coherence of the Baltic Sea MPA networks were not considered in this assessment, such as quality of the areas (e.g. water quality, oxygen depleted areas, areas of strong human impact) or currents facilitating propagule dispersal among marine landscape and habitat patches. While adding accuracy and relevance, however, they would have also considerably increased the complexity of this large scale assessment.

The ultimate goal for the future is, of course, to base the assessment of ecological coherence of the MPA networks on good ecological data; full coverage data on distribution of habitats and species. Achieving this goal is still far ahead, as biological data is currently scarce. Due to increasing pressures on the marine environment, however, and resulting needs for marine spatial planning, there are currently several mapping projects for marine biodiversity ongoing in the Baltic Sea countries. In addition to data on the distribution of species and habitats, better knowledge on ecological functioning of the ecosystem is also required. What are the key features to protect, how much of them should be protected, how big is a viable patch of a certain habitat or how far apart can separate patches be from each other? Although some guidance can already be found in the scientific literature, more knowledge, especially knowledge specific to the Baltic Sea, is needed.

When assessing ecological coherence of MPA networks, the choice of "viewpoints" is almost endless. What is ecologically coherent from the perspective of a mobile species with high dispersal ability is most likely not coherent for a sessile species with low dispersal ability. Therefore, assessing a network, it is always important to keep in mind its aims, e.g. to protect a specific species or a habitat, or more holistic aims.

As mentioned earlier, the aim of the Natura 2000 network set in the Habitats Directive is to protect the species and habitats listed in the annexes to the Directive. To demonstrate a finer scale assessment that takes into account the *specific* aims set for the network, an assessment of the marine Natura 2000 network, using modelled distribution maps of the Habitats Directive Annex I habitats, is presented as a case study in the next chapter.

Recommendation for a new approach to designating MPAs

As mentioned in the beginning of this report, marine protected areas are an important tool in protecting the marine environment from human pressure. MPAs alone, however, without any other management measures cannot sustain a healthy marine ecosystem. They need to be combined, therefore, with other management tools, such as measures preventing eutrophication or measures regulating maritime traffic.

There are many different kinds of interest competing for the space available in the marine environment. Ideally, MPAs should be included in a broader marine spatial planning process, that would enable the location of different uses of the sea, e.g. pipelines or cables, shipping or fishing to the spaces most suitable for these purposes and simultation location of sites for nature conservation. Spatial planning in the marine environment would enable the coexistence of sustainable use and marine conservation. Tools for marine spatial planning in the Baltic Sea are presented in another BALANCE report (Ekebom, Jäänheimo & Reker 2007).

Traditionally, the MPAs in the Baltic Sea, the Natura 2000 sites and BSPAs have been designated site by site on a national basis, without regional coordination. Many designated sites are also nature reserves or national parks. These sites are often selected based on scenic or recreational value, or they aim to protect unique habitats or a specific focal species. Many marine sites in the Baltic Sea also have a terrestrial component such as an important bird or seal skerry. As a consequence, many of the marine areas that are protected, have not been selected based on the marine biodiversity values beyond the sea surface.

Identifying a network of sites that adequately represents all biodiversity of the Baltic Sea requires regional coordination as well as a systematic approach. Based on the information gathered in this assessment, a second step was taken with the aim to select sites that fill the gaps in representation of the benthic marine landscapes. A systematic regional approach to select a network of sites that represent the full range of benthic marine landscapes is described in BALANCE Interim Report No x (Liman et al. 2007). Sites that compliment the existing Natura 2000 SACs were selected so that the existing and selected sites together represent all benthic marine landscapes. Three separate scenarios were considered, representation of at least 20%, 10% and 30% of all benthic marine landscapes in the Baltic Sea, Kattegat and Skagerrak.

In order to move forward in developing an ecologically coherent network of MPAs in the Baltic Sea the obvious and identified gaps in the existing networks first need to be filled. In parallel, more data on the distribution of species and habitats as well as ecological knowledge on the requirements of these species are needed in order to revise and improve the basis and criteria used in the network planning. Based on the ecological knowledge, it is very important to formulate clear objectives, targets and criteria for the MPA network. These goals should be agreed upon in an appropriate political or management setting to ensure transparency of the process. In conclusion, tools, methods and advice on how to achieve an ecologically coherent MPA network can be given by the scientific community and projects such as BALANCE, but in the end, the implementation depends on EU Member States and HELCOM Contracting Parties.

5 CASE STUDY – ECOLOGICAL COHERENCE OF THE NATURA 2000 NETWORK IN A PILOT AREA

The ecological coherence of the Natura 2000 network was also assessed at a finer scale in a pilot area in the northern Baltic Sea: Swedish Archipelago – Åland – Archipelago Sea (Figure 27).

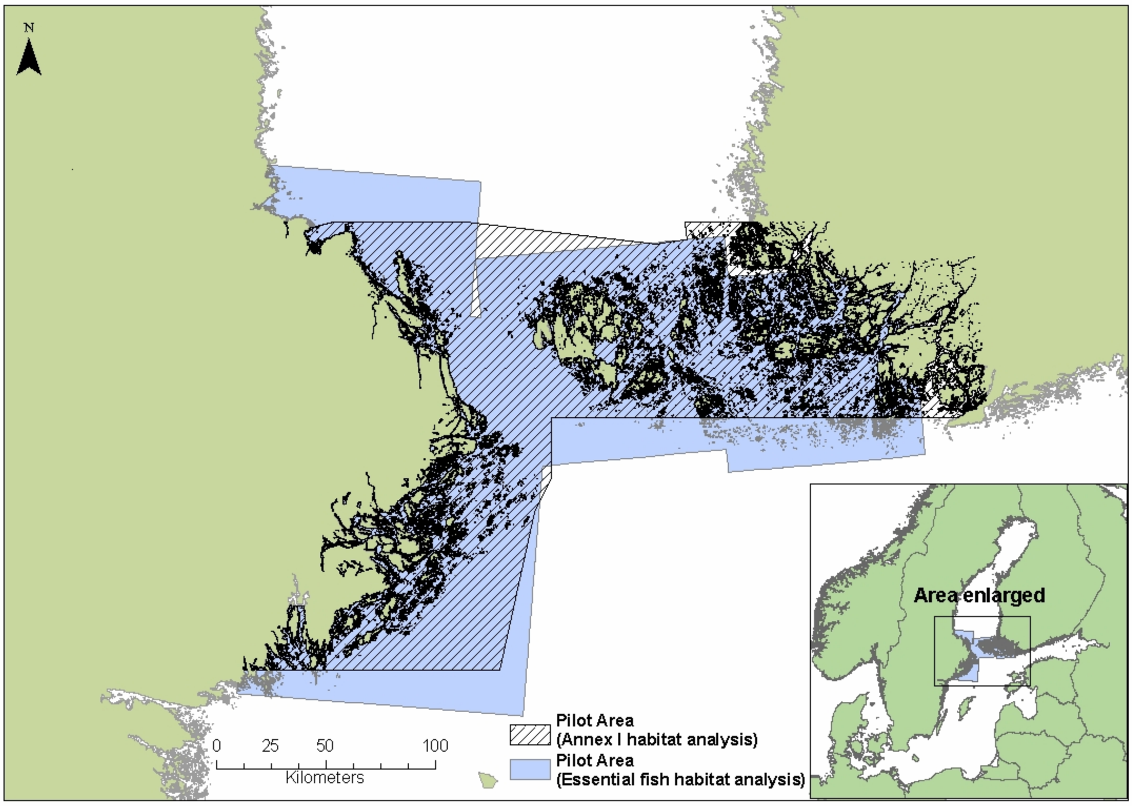


Figure 27. Delineation of the pilot area. The pilot area delineation used in the Habitats Directive Annex I habitat analysis is shown hatched and the delineation used in the essential fish habitat analysis is shown in light blue.

The aim of this finer scale assessment was to assess the ecological coherence of the Natura 2000 network from the habitat perspective. Particularly, the network was evaluated with regard to the marine Habitats Directive Annex I habitats (hereafter referred to as Natura 2000 habitats), which are the habitats that the network actually aims to protect, as well as essential fish habitats. Although the Natura 2000 legislation does not include protection of fish, the sites protected by the Habitats Directive are likely to maintain a higher quality of habitats for many fishes, compared to marine areas that are not protected. Fish recruitment has been shown to decrease due to human impacts, such as boating, pollution and dredging (Eriksson et al 2004, Sandström et al 2005). By supporting habitats important for fish spawning and feeding, Special Areas of Conservation (SAC) may help maintain viable populations of both commercial and non-commercial fish stocks. Primarily, the juvenile stages of fishes may be expected to gain from the protection of Natura 2000 habitats, as these stages are often highly dependent on specific habitat types (Bergström L. et al. 2007).

For the analysis of Natura 2000 habitats, maps of all of the marine habitats were unavailable for the whole pilot area and therefore only six of the habitats were used in the assessment. The habitat maps used were produced by GIS modelling within the BALANCE project (Dinesen et al. 2007). The maps used in this assessment, however, are an earlier version of the maps presented in Dinesen et al (2007) and are therefore somewhat different. One should also keep in mind that the maps used are based on predictive modelling and may therefore not display the real distribution patterns of the Natura 2000 habitats. Only the marine (underwater) parts of the following habitats were included in the assessment.

1. Estuaries (1130)
2. Coastal lagoons (1150*)
3. Large shallow inlets and bays (1160)
4. Reefs (1170)
5. Esker islands
6. Boreal Baltic islets and small islands (1620)

* Priority habitat according to the Habitats Directive

When interpreting the results of the assessment, it is important to keep in mind that when assessing coherence of these Natura 2000 habitats, all marine Natura 2000 sites were used in the analysis (except for those that did not fulfil adequacy criteria, see chapter 5.2). Therefore the results may give an overestimate of the actual protection of these habitats, as only habitats for which a site is designated is protected within a Natura 2000 site. This means that if a habitat is not mentioned in the list of Annex I habitats occurring in a particular site, the habitat is not protected even if it might be present within the site.

The essential fish habitat maps used in the assessment were;

1. Spawning habitats for perch
2. Nursery habitats for perch
3. Nursery habitats for pike
4. Nursery habitats for roach
5. Nursery habitats for pikeperch

5.1 Preparation of datasets and delineation of the pilot area

All input datasets were converted to a common geographic reference system, a projection of UTM43N using WGS84 datum. The northern and southern borders of the pilot area were defined by the coverage of the habitat maps available for the assessment. The pilot area delineation used in the assessment of essential fish habitats differed to some extent from the delineation used in the assessment of Natura 2000 habitats due to a difference in the extent of the essential fish habitat maps to the extent of the Annex I habitat maps.

The methods for creating the habitat maps of Natura 2000 habitats and the maps of essential fish habitats used in this assessment are described in chapter 3.2.

Delineating boundaries for designated Natura 2000 Special Areas of Conservation (SACs) designated under the Habitats Directive and Special Protection Areas (SPAs) designated under the Birds Directive were compiled from national data bases (Finland and Sweden). The separate national polygon layers (or maps) were merged to form two uniform mask layers, representing the SAC and SPA sites respectively. A third layer representing the total coverage of Natura 2000 sites was created by joining SAC and SPA sites. The coastline polygon used to separate terrestrial areas from marine areas had an estimated resolution of 1:20 000.

5.2 Assessment of adequacy

As part of the adequacy assessment of the Natura 2000 network, the size distribution of the Natura 2000 areas in the pilot area was studied. Adequacy criteria were also incorporated in other parts of the assessment (representation, replication and connectivity). Only sites/habitats considered to be of sufficient size were included in the assessment of Natura 2000 habitats (Table 12). When assessing essential fish habitats, only the habitat patches that were considered large enough to support fish recruitment were included in the assessment.

Adequacy criteria applied

Habitat scale:

Ideally, the size of an MPA aiming to protect a certain habitat or species should be defined as a minimum area that supports the habitat or the species population using that habitat. Such criteria are difficult to set, however, as there is very little scientific advice on minimum sizes for viable habitats. In this assessment, an attempt was made to set minimum sizes for MPAs (in this case Natura areas) that would adequately protect the Natura 2000 habitats (Table 12). When determining minimum sizes for areas, the mean and minimum sizes of the modelled habitats were used as a guideline. Also, size guidelines for some Annex I habitats set by Finland and Sweden in their habitat descriptions were considered (e.g. large shallow bays). The shape of the MPAs and their quality (in terms of water quality or potential threats) were not considered in this assessment.

For essential fish habitats, the adequacy criteria was considered in the sizes of the habitats. Only habitat patches over 1ha in size were included in the assessment (representation and connectivity) as these were considered to be of sufficient size to support recruitment of the studied species.

Table 12. The minimum sizes for a Natura areas (SACs or SACs and SPA combined) to be considered adequate for different Natura 2000 habitats. Natura areas smaller than the minimum were excluded from the assessment.	
Natura 2000 habitat	**Minimum size for Natura area**
Estuaries (1130)	Fin 20ha/ Swe 1ha*
Coastal lagoons (1150)	1ha
Large shallow inlets and bays (1160)	20ha
Reefs (1170)	1ha
Esker islands (1610)	1ha
Boreal Baltic islets and small islands (1620)	1ha

* The size difference is due to differences in the criteria when modelling the habitats (Dinesen et al. 2007).

5.2.1 Assessment methodology

As in the Baltic Sea scale analysis, some of the Natura 2000 sites in the pilot area consisted of several separate patches and some sites together formed one larger patch. One good example is the Archipelago Sea National Park in Finland, which is named as one site, but is actually composed of almost 6000 separate protected areas. As we were interested in the sizes of the protected patches, not the sizes of the sites, some further operations were performed on the Natura 2000 layers. Firstly, all of the SAC sites were dissolved in order to create one multipart polygon. Then the polygon was divided into single part patches. This way all SAC sites that shared a common boundary were combined and the sites that consisted of several unconnected patches were separated. After adding the SPAs to the SACs, a similar process was carried out again to dissolve SPAs into the SACs creating single part sites. Finally the size distribution of the Natura 2000 areas was calculated.

5.2.2 Results and discussion

The size distribution of the marine SACs in the pilot area is strongly biased towards small sites (Figure 28). Only a small fraction of the areas are over 1000 ha in size. Although SPAs are generally larger than the SACs, adding the SPAs to the network would not improve the situation very much.

The small size of the sites results in many of the generally larger habitats, e.g. *estuaries* or *large shallow inlets and bays* being only partly protected or possibly fragmented into different sites. This can be regarded as a major shortcoming of the sites, as the habitats that the network aims to protect, should ideally be completely within the sites. This issue is further discussed in the chapter on replication (chapter 5.4.2).

The small size of the sites also reduces possibilities for within network dispersal of short distance dispersers. If the habitats are protected only in small sites that are not placed carefully to support connectivity, the short distance dispersers are not able to disperse from one protected area to another. The larger sites are likely to support several separate habitat patches and therefore also secure connectivity between these patches (see also chapter 5.5.2. on connectivity).

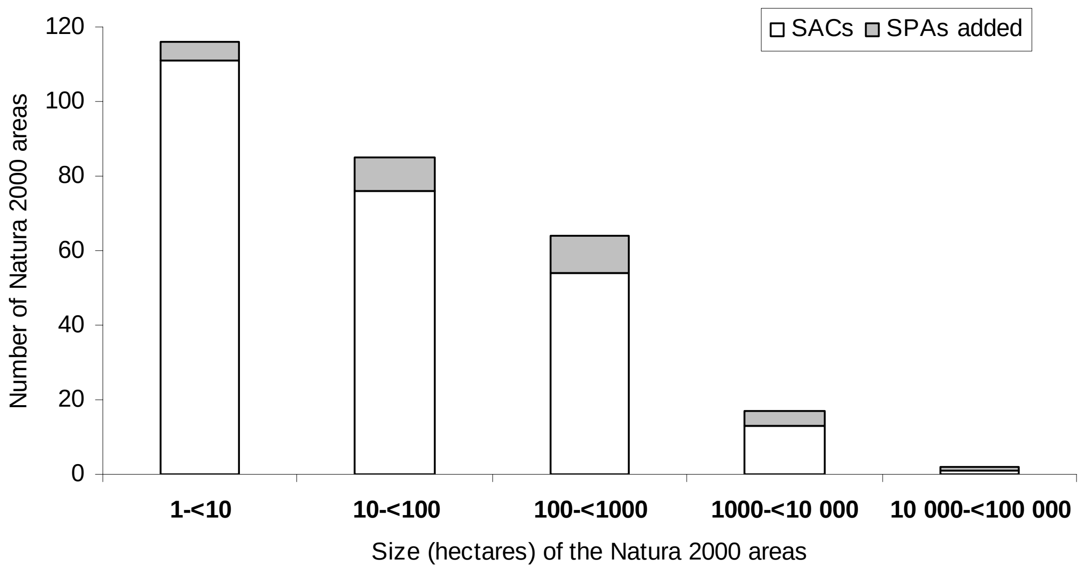


Figure 28. Size distribution of the SACs in the pilot area and if the SPA sites were added to SACs. Note that the coverage of SPA sites alone cannot be read from the graph since there is overlap in areas between the two networks. Areas smaller than 1ha are not included in the analysis.

5.3 Assessment of representation

In the representation assessment, the proportion of protected Natura 2000 habitats and essential fish habitats was calculated. The geographical representation of the Natura 2000 areas in the pilot area was also studied.

Representation criteria applied

Habitat scale:

The European Commission uses 20% and 60% (the latter for priority habitats) representation as a guiding principle for sufficient protection of the individual habitats. The same values are used in this assessment to indicate the level of sufficient representation of the Natura 2000 habitats (Table 13). The representation level of 20% has also been used to indicate a sufficient level for the essential fish habitats.

Table 13. Representation criteria for Natura 2000 habitats in the pilot area.

Natura 2000 Habitat	Representation (%)
Estuaries (1130)	20
Coastal lagoons (1150*)	60
Large shallow inlets and bays (1160)	20
Reefs (1170)	20
Esker islands (1610)	20
Boreal Baltic islets and small islands (1620)	20

* Priority habitat according to the Habitats Directive

5.3.1 Assessment methodology

When calculating geographical representation of the Natura 2000 areas, the size of the pilot area was compared to the total area coverage of the SACs within the pilot area. The same was done for the SAC and SPA sites combined.

When calculating representation of the Natura 2000 habitats, the habitats that were inside a protected area were first identified by intersecting the Natura 2000 habitat maps with the SACs and also with the SACs and SPAs combined. Only protected areas considered adequate for protection of the habitat in question were included in the assessment (see Table 12). Habitat representation was calculated as the area of protected Natura 2000 habitat in relation to the total area of the habitat. The analysis was performed separately for each habitat.

When assessing representation of essential fish habitats (EFHs), the raster format maps of EFHs were transformed to polygons. To account for requirements of adequacy, only EFHs larger than 1ha were included. EFHs that are within SAC sites were identified by clipping the EFH maps with the SACs. Representation was calculated as the area of protected EFHs in relation to the area of all EFHs. The analysis was performed separately for each species and life stage assessed.

5.3.2 Results and discussion on the Natura 2000 habitat assessment

The proportion of total marine area within the pilot area's SAC network and SAC-SPA network were 3.3% and 5.2% respectively. It should be noted that these values are largely dependent on the delineation of the pilot area.

The assessment of representation of the six Natura 2000 habitats in the pilot area shows that none of the habitats are adequately represented, i.e. fulfilling the minimum requirement of 20% representation or 60% percent representation in the case of *coastal lagoons* (Table 14). Adding SPAs to the SAC protection improves the representation of *estuaries* from 2.8% to 11%. The representation of the other habitats is only slightly improved by added SPA protection.

Table 14. Representation of Natura 2000 habitats in pilot area 3, with estimation of their number, total area and protected area within SACs and within the SACs and SPAs combined.

Natura 2000 habitat	Total number	Total habitat area (km^2)	Total protected area (km^2)		Representation (%)	
			SAC	SAC+SPA	SAC	SAC+SPA
Estuaries (1130)	87	123	3	14	2.8	11.0
Coastal lagoons (1150*)	4436	16	2	3	15.4	16.4
Large shallow inlets and bays (1160)	529	363	29	34	7.9	9.3
Reefs (1170)	22322	361	17	26	4.6	7.1
Esker islands (1610)	252	30	5	5	16.1	16.2
Boreal Baltic islets and small islands (1620)	36685	1177	87	117	7.4	10.0
Total	64311	2069	143	197	6.9	9.5

It can be concluded that all of the Natura 2000 habitats are currently inadequately represented within the Natura 2000 network, irrespective of whether SPAs are added to the assessment or not. The priority habitat *coastal lagoons* is especially far from the 60% target level of representation set in the Habitats Directive.

In order to improve the representation of Natura 2000 habitats in the network, new SACs including marine Natura 2000 habitats should be designated. One of the main reasons for the current inadequate representation of the habitats is most likely the lack of knowledge on the distribution of the habitats. Therefore, in order to reach better representation, more knowledge is definitely needed. The use of modelled distribution maps of these habitats has already shown that clear gaps in representation exist, but for designation of new sites, more accurate data gathered in the field is necessary.

5.3.3 Results and discussion on the fish habitat assessment

The study area for the fish habitat assessment was somewhat larger than the area of the Natura 2000 habitat assessment (Figure 27), and included a substantially larger total of SACs. The SAC network covered 5.4% of the total sea area used in the assessment of fish habitats. Compared to the area used for the Natura 2000 habitat assessment, this delineation is extended and since different total areas were assessed, the figures presented for EFHs can not be directly related to the results of the Natura 2000 habitat assessment.

Despite a higher proportion of SACs by this delineation, the protection level of all EFHs studied are well below the 20% guideline level. Biases in representation are identified by relating the representation values of essential fish habitats (Table 15) to the proportion of total sea area included as SACs (5.4%). Nursery areas for perch are slightly above this value, whereas the other EFHs studied are under-represented. For most studied species the area of protected recruitment habitats is actually smaller than if the Natura 2000 sites had been designated randomly within the study area. Poor representation of the essential fish habitats within the SAC network can be related to the poor representation of the Natura 2000 habitats, as the shallow vegetated habitats (e.g. *estuaries, large shallow inlets and bays, coastal lagoons etc.*) are often also important habitats for fish.

Table 15. Representation of essential fish habitats (EFH) in pilot area 3, with estimation of their number, area and protected area.

	Total number	Total EFH area (km^2)	Total protected EFH area (km^2)	Representativity (%)
Spawning habitats for perch	3182	130	5	3.8
Nursery habitats for perch	13923	2160	129	6.0
Nursery habitats for pike	6503	400	18	4.6
Nursery habitats for roach	14067	1800	90	5.0
Nursery habitats for pikeperch	6652	1030	36	3.5

5.4 Assessment of replication

The analysis of replication was carried out in order to count the number of protected patches of each Natura 2000 habitat within the Natura 2000 network. The number of Natura areas hosting these patches was also calculated.

Replication criteria applied

Habitat scale:
When assessing replication of the Natura 2000 habitats within the Natura 2000 network, the modelled habitat maps of six Natura 2000 habitats were used. If the protected patch of an estuary or a large shallow bay (which are generally large habitats) was less than 0.1ha, it was not considered as a replicate. For all other habitats, no minimum size for a replicate was set, as some of the habitats are generally very small (e.g. reefs or lagoons). If a large habitat was protected by several separate Natura areas, it was still considered as one replicate. No specific number for an adequate amount of replicates was set, but a low number of replicates would indicate a possible gap in replication. To examine the distribution of the habitats between the Natura 2000 areas, also the number of MPAs hosting the protected patches was calculated.

5.4.1 Assessment methodology

The habitats that were inside Natura 2000 SAC sites were first identified by an overlay analysis. Only SACs considered adequate in size for the protection of the habitat in question were included in the assessment (see Table 12). In some cases, the SACs covered only a minimal part of a large habitat (e.g. $100m^2$ of an estuary). In these cases, the patches were not included in the analysis. The number of habitat patches (replicates) and the mean sizes for patches within the SACs were calculated for each habitat type. Similarly, the number of sites hosting the habitat replicates was calculated. The same analyses were carried out using the SACs and SPAs combined.

5.4.2 Results and discussion of the Natura 2000 habitat assessment

The replication analysis showed that most of the assessed Natura 2000 habitats have a relatively large number of patches within the Natura 2000 network (Table 16). This is most likely due to the natural patchiness of many of these habitats, which results in many patches also existing within the protected areas. *Estuaries,* however, have only eight replicates within SACs and only one of these is a whole estuary. Partial protection also seems to be the problem with other habitats, especially the ones that are generally larger. Most of the habitat patches are not completely within the SAC sites. In order to efficiently protect a habitat, the recommendation should be that the whole habitat is included within the site and sometimes even buffer zones are recommended. Therefore, more emphasis should be set on placing and delineating the sites more carefully. The partial coverage of the underwater habitats within the SACs, however, most likely results from the lack of knowledge on the distribution of the habitats. Therefore, more field data on the distribution of the habitats is needed in order to improve their protection.

The replicates of the Natura 2000 habitats were also often unevenly distributed across the pilot area. This is further discussed in the connectivity section (chapter 5.5.2) where distribution areas of protected habitats are also shown.

The inclusion of SPAs to the network did not increase replication substantially. The only significant improvement was that the mean size of the protected estuaries increased from 43 hectares to 123 hectares.

Table 16. Number of replicates (protected patches) of Natura 2000 habitats within SACs and within the SACs and SPAs combined. The number of MPAs shows the number of Natura areas that host these patches and the mean size of the protected patches is presented in the last column.

Natura 2000 habitat	**Total number of patches**	**Number of replicates In SACs / SACs+SPAs**	**Number of MPAs SACs / SACs+SPAs**	**Mean size (ha) of a protected patch In SACs / SACs+SPAs**
Estuaries (1130)	87	8 / 11	9 / 17	42.8 / 122.8
Coastal lagoons (1150)	4436	434 / 506	72 / 81	0.6 / 0.5
Large shallow inlets and bays (1160)	529	42 / 43	30 / 32	68.4 / 78.5
Reefs (1170)	22322	1069 / 1547	82 / 90	1.6 / 1.7
Esker islands (1610)*	252	21 / 22	10 / 11	22.7 / 21.8
Boreal Baltic islets and small islands (1620)*	36685	5717 / 6033	74 / 85	1.5 / 1.9

*Only underwater parts of the habitat included in the analysis

5.5 *Assessment of connectivity*

Connectivity assessments were carried out for SACs only. The connectivity of Natura 2000 habitats was assessed by using dispersal distances of 1km and 25km that fit the approximate dispersal potential of some of the species occurring in these habitats. For essential fish habitats (EFHs) the connectivity assessment was carried out for spawning areas of perch and nursery areas of pike using dispersal distances estimated by studies of migratory behaviour.

Connectivity criteria applied

Habitat scale:
When analyzing connectivity of Natura 2000 Annex I habitats, distances of 1km and 25km were used. These distances were determined by average or maximum dispersal distances of species occurring in these habitats. The species are presented in Table 17. The species that were chosen to determine the distances are wide spread (covering the whole pilot area) and they use different dispersal strategies. For estuaries, only a 25km distance was used, as they are generally relatively far from each other and therefore connectivity between them with 1km dispersal distance was not expected. Habitat patches with less than three connections to other patches were not considered as connected.

For essential fish habitats, spatially explicit analyses were performed for spawning areas of perch and nursery areas of pike. The migration distance for perch was set to 10km, and for pike to 5km (Saulamo & Neumann 2002). EFHs with less than three connections to other EFHs were not considered connected.

Table 17. Connectivity criteria for Natura habitats in Pilot area 3. Examples of species that fit the connectivity criteria are given in the table.		
Natura 2000 habitat	**Connectivity criterion 1km**	**Connectivity criterion 25km**
Estuaries (1130)		*Asellus aquaticus*[3], *Perca fluviatilis*[4], *Esox lucius*[5]
Coastal lagoons (1150*)	*Chara* spp.[1]	*Asellus aquaticus*[3], *Esox lucius*[5]
Large shallow inlets and bays (1160)	*Zostera marina*[2]	*Idotea chelipes*[3], *Sander lucioperca*[6]
Reefs (1170)	*Fucus vesiculosus*[6]	*Gammarus* spp.[3], *Ulva* spp.[8]
Esker islands (1610)	*Fucus vesiculosus*[7]	*Cladophora glomerata*[7], *Ulva* spp.[8], *Platichtys flesus*[9]
Boreal Baltic islets and small islands (1620)	*Fucus vesiculosus*[7]	*Gammarus* spp.[3], *Ulva* spp.[8]

[1] Van den Berg et al. 2001, [2] Dispersal by drifting adult plants (Harwell & Orth 2002 and references therein), [3] Based on invertebrate swimming speed (Alexander & Chen 1990, [4] Böhling& Lehtonen 1984, Finnish Game and Fisheries Institute: http://www.rktl.fi/kala/tietoa_kalalajeista/ahven/, [5] Lehtonen 1977, Karås & Lehtonen 1990, Laikre et al. 2005, [6] Lehtonen 1979, Lehtonen & Toivonen 1987, [7] based on other fucoids (Gaylord et al. 2002), [8] Zechman & Mathieson 1985, Norton 1992, [9] Otterlind 1967, Aro & Sjöblom 1983, Aro 1989 and references therein,

5.5.1 Assessment methodology

The level of connectivity was assessed 1) for all habitats, regardless of whether or not they were protected, and 2) for protected habitats only (within SACs). The analysis on all habitats provides a measure of the potential level of connectivity within the whole pilot area, and may serve as a reference level on how the SAC network may be improved. This spatially explicit connectivity analysis offers a way to visualise where connectivity among protected habitats is sufficient and where it is not. The level of connectivity of habitats within the SAC network was assessed by comparing the total connected area within the connectivity range of protected habitats with the total connected area within the connectivity range all habitats (i.e. unprotected habitats also included).

The connectivity analysis carried out in the pilot area is based on an analysis of cost distance, which recognizes land areas as obstacles to migration. A raster layer identifying sea and land surface areas (a sea mask) was used as cost raster and the polygon map of protected habitats (or all habitats when assessing potential connectivity) was used as a source layer. The output raster of the cost distance analysis shows the shortest distance to a habitat for each cell. Cells lying within a distance to a habitat corresponding to half the migration distance are defined as being within the connectivity range.

When assessing connectivity of the Natura 2000 habitats within SACs, only habitats within those SACs that were considered adequate in size for the habitat in question were included in the analysis (see Table 12). For *estuaries* and *large shallow inlets and bays*, that are generally large habitats, protected patches smaller than 0.1ha were excluded. For essential fish habitats, only EFHs larger than 1ha were included in the analysis. Habitats that had less than three connections to other corresponding habitats were not regarded as connected.

5.5.2 Results and discussion on the Natura 2000 habitat assessment

Estuaries (1130)

As e*stuaries* generally occur relatively far from each other, the connectivity assessment was carried out using only a 25km dispersal distance. Potential connectivity between *Estuaries* was found to be better on the Swedish side of the pilot area, as a lot more (and smaller) *estuaries* were identified by modelling there than on the Finnish side. Even on the Swedish side, however, the SAC network does not support connectivity between *estuaries* (Figure 29). This is not surprising as out of 87 *estuaries* identified by modelling, only eight were partly within the SACs and only one of them completely. This can be regarded as a major gap in the protection of *estuaries*.

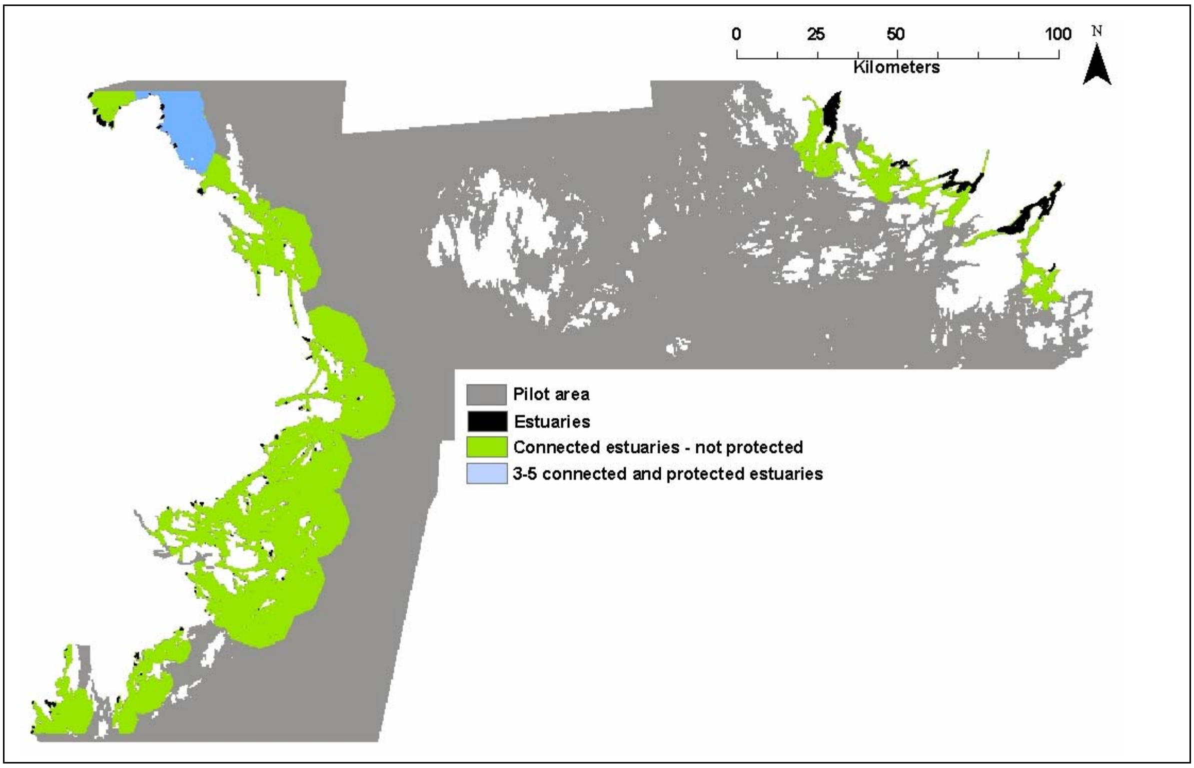


Figure 29. Connectivity of Estuaries (1130). Blue areas include at least 3 connected and protected estuaries using 25km dispersal distance. Green areas represent connected but unprotected estuaries.

Coastal lagoons (1150*)

As *coastal lagoons* identified by modelling are high in numbers and relatively evenly spread throughout the pilot area, they show good potential for connectivity, especially using the 25km dispersal distance. With 1km dispersal distance lagoons form smaller clusters (Figure 30) but relatively few are left with no connections to the neighbouring lagoons. Out of 4436 lagoons identified by modelling, 434 are at least partly within the SAC network. When using the 25km dispersal distance, in some areas the lagoons within SACs form relatively large connected clusters including many lagoons. Areas with no connectivity between protected lagoons, however, were also identified (e.g. a large area in the Finnish archipelago and a large area in the western and southern parts of Åland, Figure 30a). In total, the areas within the dispersal range of 25km from protected lagoons (blue areas in Figure 30) cover about half of the potential dispersal areas of all lagoons (green areas in Figure 30, Table 18). When using the 1km dispersal distance only a few small areas with relatively good connectivity between protected lagoons were identified.

The area within the dispersal range of protected lagoons is only 9% of the potential dispersal areas of all lagoons (Table 18).

Table 18. Estimation of area covered by dispersal.

Natura 2000 habitat	Dispersal distance (km)	Area within dispersal range (ha)	Area within dispersal range of *protected* habitats (ha)	Proportion of area within dispersal range of protected habitats (%)
Estuaries (1130)	25	59 860	9 730	16.3
Coastal lagoons (1150*)	25	292 710	152 540	52.1
	1	42 550	3 970	9.3
Large shallow inlets and bays (1160)	25	229 190	70 120	30.6
	1	21 300	2 770	13.0
Reefs (1170)	25	317 020	196 760	62.1
	1	175 270	13 500	7.7
Esker islands (1610)	25	94 170	26 860	28.5
	1	5 500	1 140	20.7
Boreal Baltic islets and small islands (1620)	25	309 620	186 470	60.2
	1	152 470	13 820	9.1

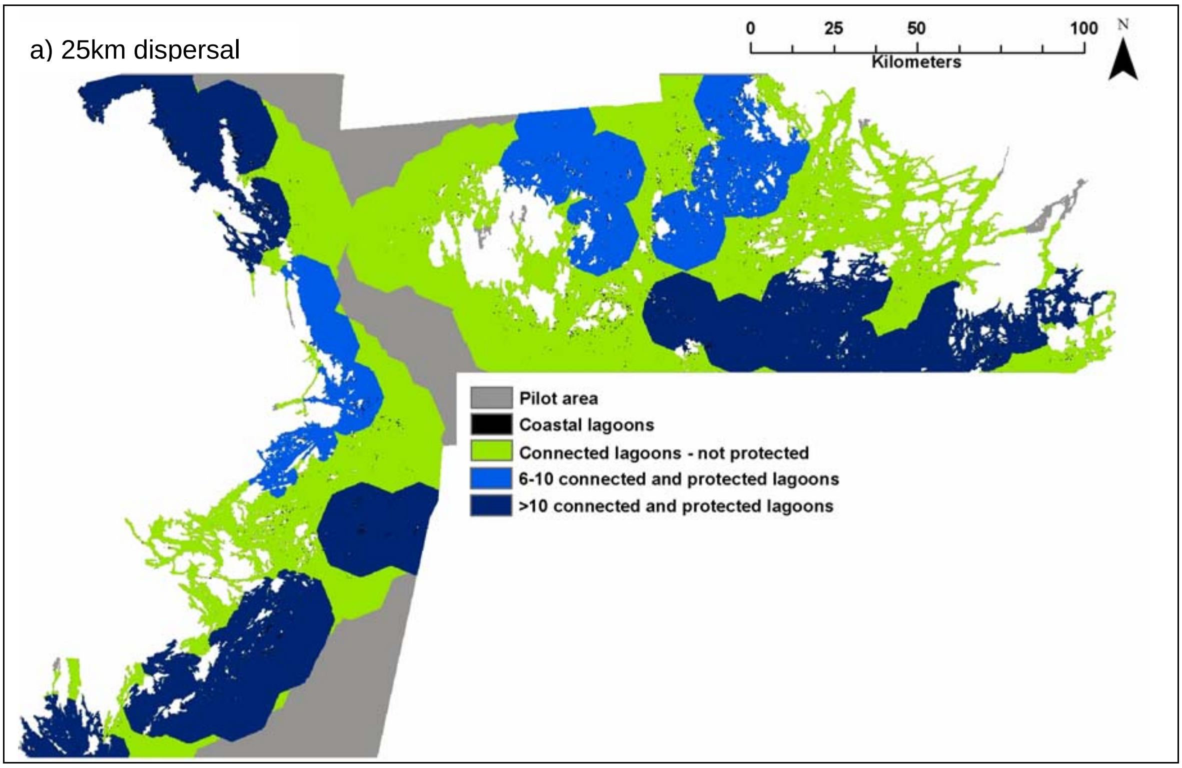
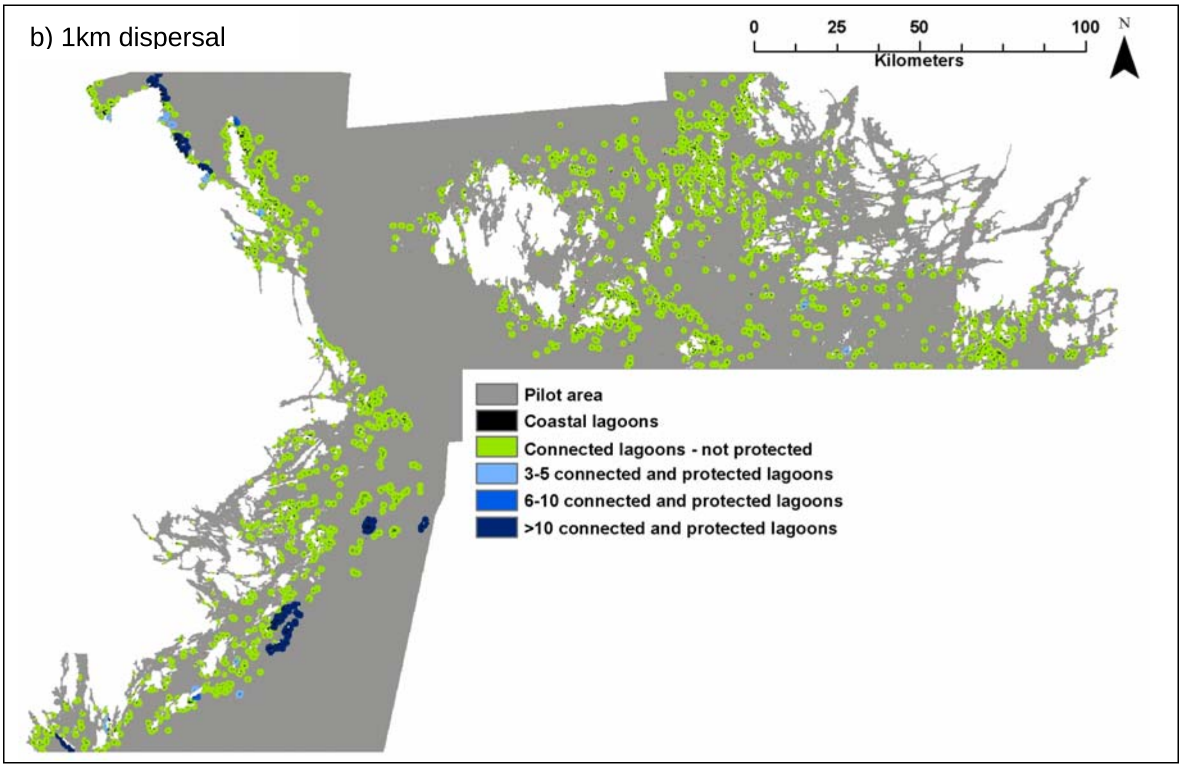


Figure 30. Connectivity of coastal lagoons (1150). Blue areas include at least 3 connected and protected coastal lagoons a) using 25km dispersal distance and b) using 1km dispersal distance (see next page). Green areas represent dispersal ranges from unprotected lagoons.*



Large shallow inlets and bays (1160)

The large shallow inlets and bays identified by modelling were evenly spread throughout the pilot area and therefore show good potential for connectivity when using the 25km dispersal distance. The only gap in the connectivity range of the bays is the open sea area between Sweden and Finland (Figure 31a). When using the 1km dispersal distance, however, the potential connectivity of *large shallow bays* was relatively bad, especially on the Finnish side (Figure 31b). Therefore, no good connectivity of protected patches was expected. Out of 529 *large shallow bays* identified by modelling, 44 are at least partly within the SAC network. Only four of the protected patches are on the Finnish side. As a consequence, when using the 25km dispersal distance, the *large shallow bays* within SACs form relatively large connected clusters by the coast of Sweden, in the northern and southern parts of the pilot area, but on the Finnish side there are no protected bays that are connected to each other (Figure 31a). In total, the areas within the dispersal range of protected *large shallow bays* (blue areas) cover about 30% of the potential dispersal areas of all *large shallow bays* (green areas, Table 18). As expected from the low potential for connectivity using 1km dispersal distance, only a few small areas with connectivity between protected *large shallow bays* were identified.

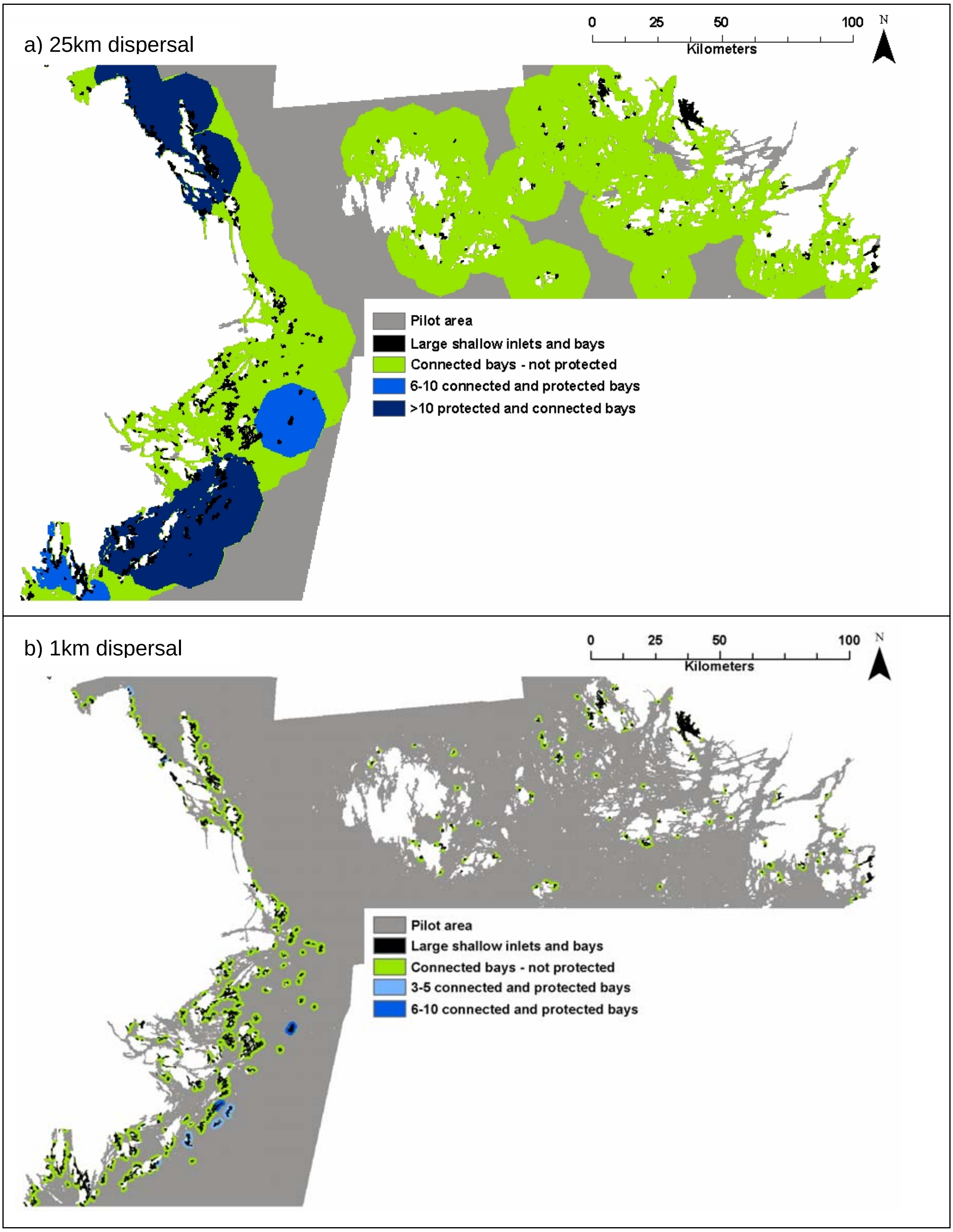


Figure 31. Connectivity of large shallow inlets and bays (1160). Blue areas include at least 3 connected and protected large shallow inlets and bays a) using 25km dispersal distance and b) using 1km dispersal distance. Green areas represent dispersal ranges from unprotected large shallow inlets and bays.

Reefs (1170)

The reefs identified by modelling are numerous and spread throughout the whole pilot area. They show good potential for connectivity both when using the 25km dispersal distance and when using the 1km dispersal distance (Figure 32). Out of 22322 *reefs* identified by modelling, 1069 were at least partly within the SAC network. When using the

25km dispersal distance, the *reefs* within SACs form relatively large connected clusters in the whole pilot area (Figure 32a). In total, the areas within the dispersal range of protected *reefs* (blue areas) cover about 60% the potential dispersal areas of all *reefs* (green areas, Table 18). In contrast, the areas within the 1km dispersal range of protected *reefs* (blue areas) cover only about 8% of the potential connected areas (green areas, Figure 32b). This indicates a clear gap in connectivity.

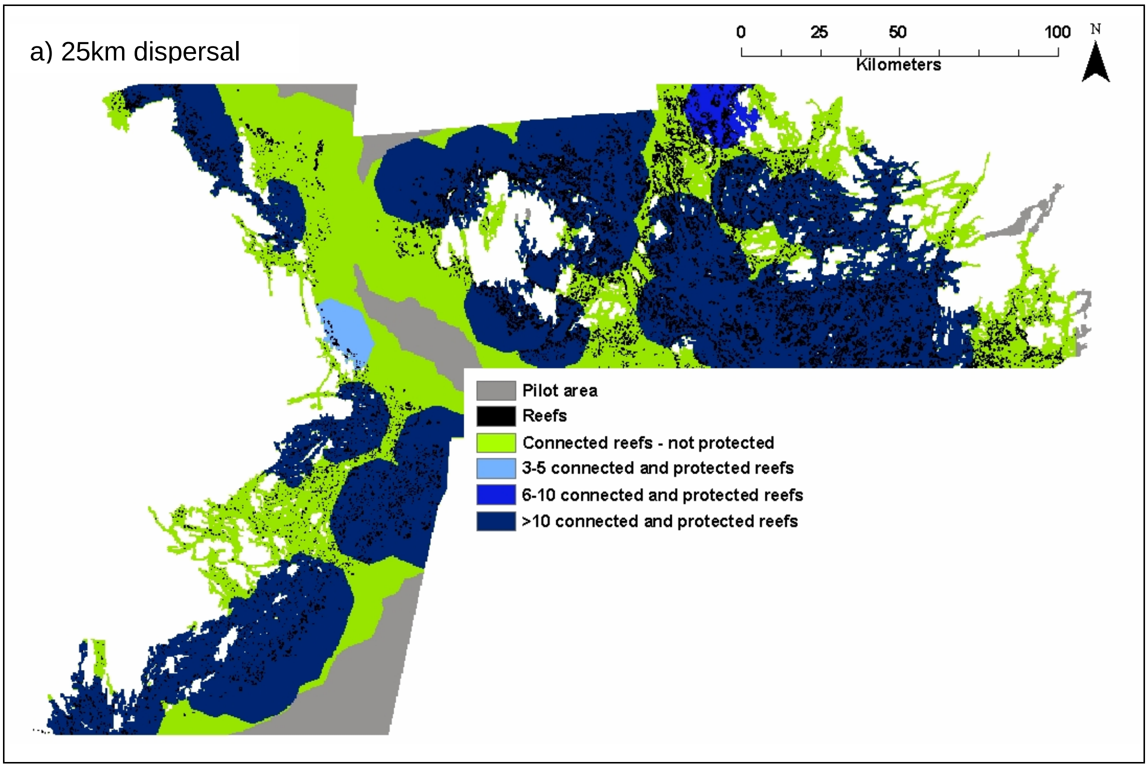
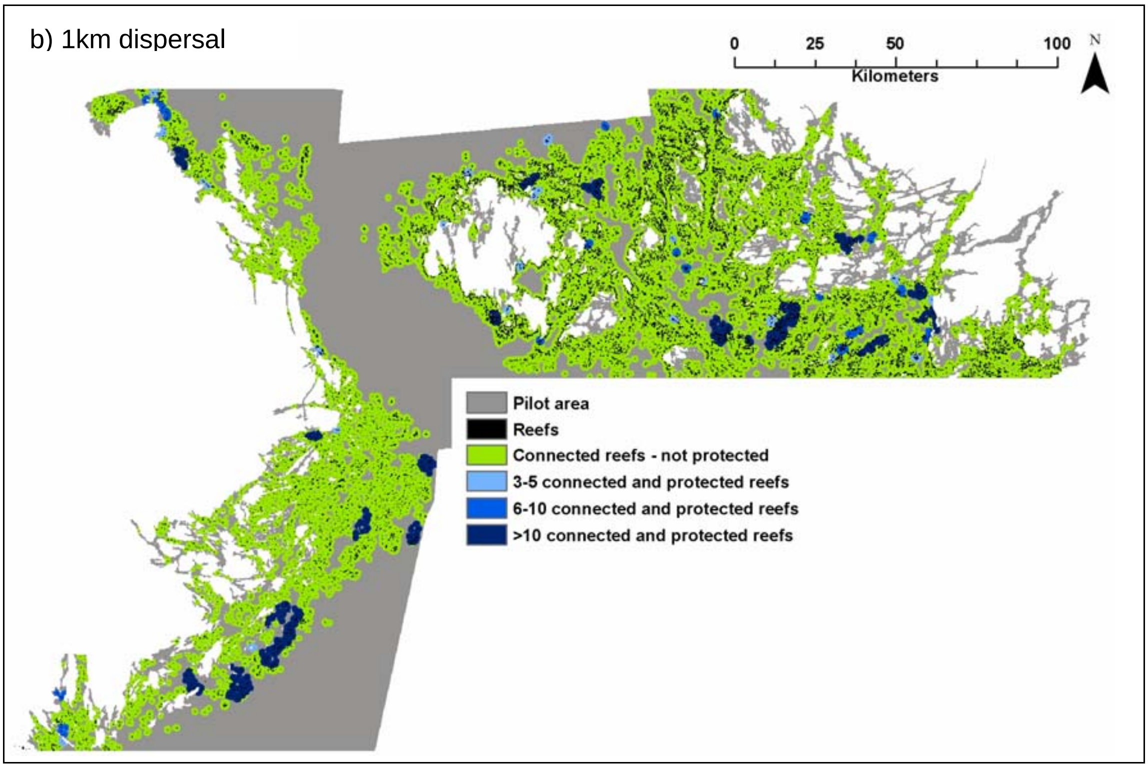


Figure 32. Connectivity of reefs (1170). Blue areas include at least 3 connected and protected reefs a) using 25km dispersal distance and b) using 1km dispersal distance (see next page). Green areas represent dispersal ranges from unprotected reefs.



Esker islands (1610)
The esker islands identified by modelling are relatively sparse and are mostly concentrated into three areas; in the eastern part of the pilot area, around Åland islands and in the south-western part of the pilot area (Figure 33a). When using the 25km dispersal distance there is some potential for connectivity within these separate areas but not across the whole pilot area. When using the 1km dispersal distance there is potential for connectivity especially in the eastern part of the pilot area (Figure 33b). Out of 252 *esker islands* identified by modelling, 21 are at least partly within the SAC network. When using the 25km dispersal distance, the *esker islands* within SACs form a connected cluster in the eastern part of the pilot area by the coast of Finland (Figure 33a). In total, the areas within the dispersal range of protected *esker islands* (blue areas) cover about 30% of the potential dispersal areas of all *esker islands* (green areas, Table 18). When using the 1km dispersal distance, only a few protected *esker islands* in the eastern part of the pilot area are connected to each other (Figure 33b). They still cover about 20% of the potential areas for connectivity (green areas, table 18).

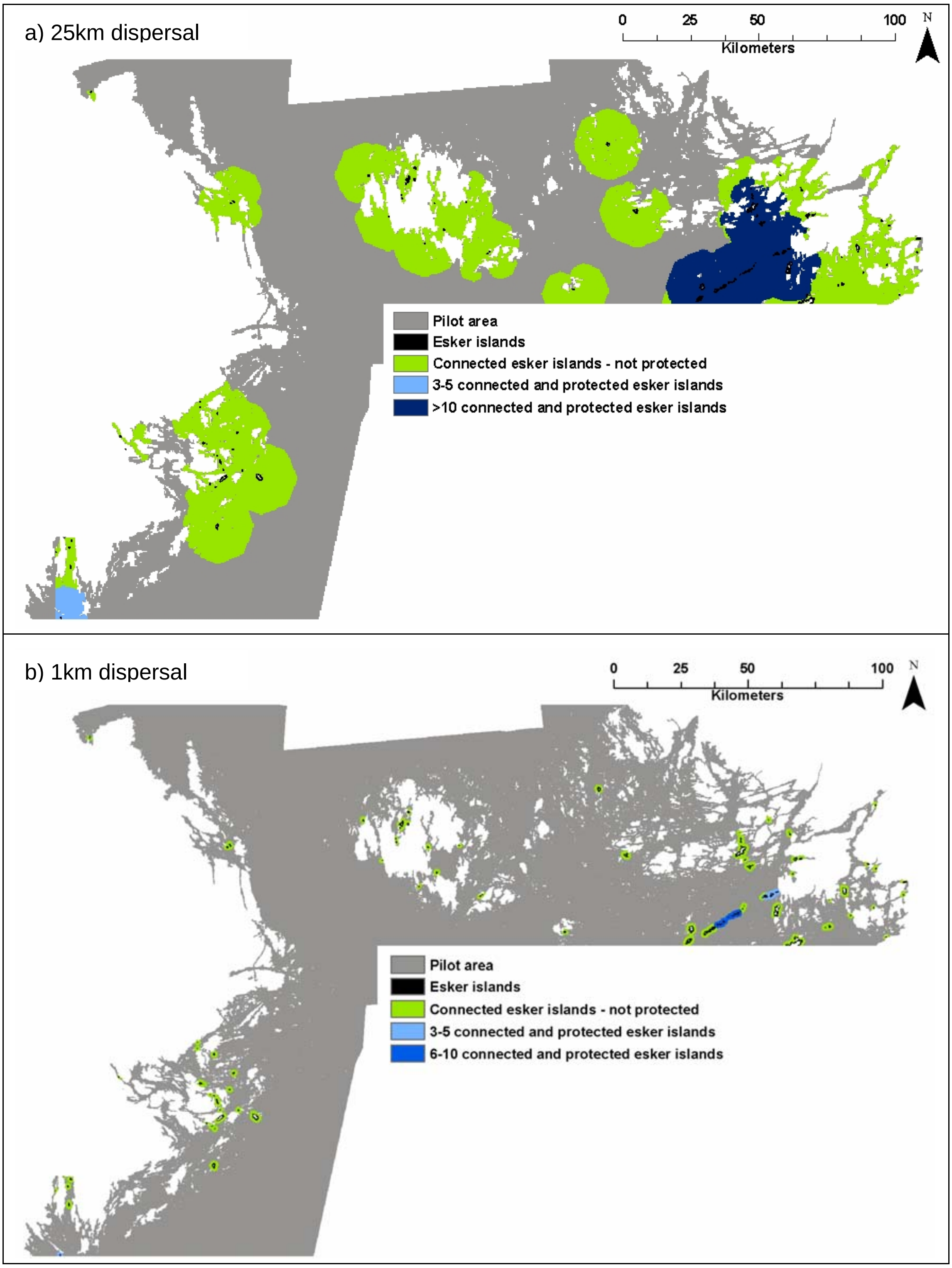


Figure 33. Connectivity of esker islands (1610). Blue areas include at least 3 connected and protected esker islands (underwater parts only) a) using 25km dispersal distance and b) using 1km dispersal distance. Green areas represent dispersal ranges from unprotected esker islands.

Boreal Baltic islets and small islands (1620)

The boreal Baltic islets and small islands are the most numerous Natura 2000 habitats identified by modelling and they are spread throughout the whole pilot area. They show good potential for connectivity both when using the 25km dispersal distance and when using the 1km dispersal distance (Figure 34). Out of 36685 islets identified by modelling, 5717 are at least partly within the SAC network. When using the 25km dispersal distance, islets within SACs form relatively large connected clusters in the whole pilot area (Figure 34a). In total, the areas within the dispersal range of protected islets (blue areas) cover about 60% the potential dispersal areas of all islets (green areas, Table 18). In contrast, the areas within the 1km dispersal range of protected islets (blue areas) cover only about 9% of the potential connected areas (green areas, Figure 34b). The connected areas of protected islets are located in the same areas as connected areas for reefs (see also Figure 32b).

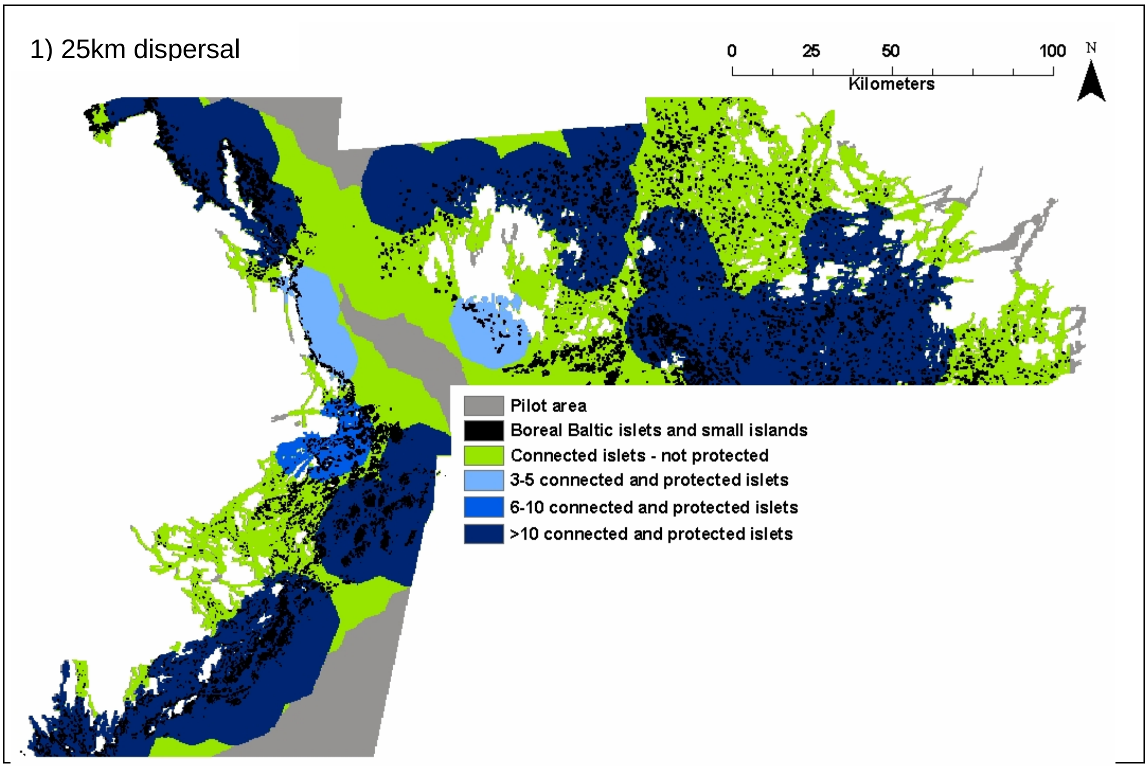
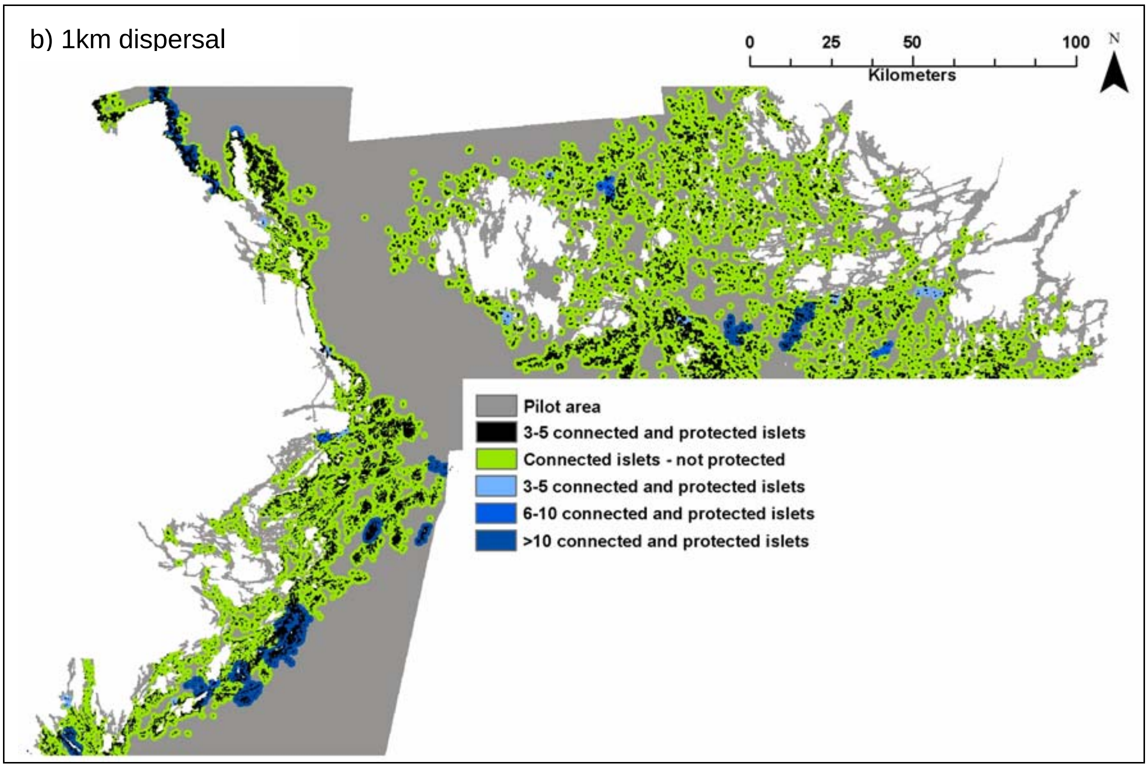


Figure 34. Connectivity of boreal Baltic islets and small islands (1620). Blue areas include at least 3 connected and protected boreal Baltic islets and small islands (underwater parts only) a) using 25km dispersal distance and b) using 1km dispersal distance (see next page). Green areas represent dispersal ranges from unprotected islets.



In summary, due to their different distribution patterns in the pilot area, the Natura 2000 habitats show differing levels of potential connectivity. Most of the habitats have good potential for connectivity, especially when looking at long-distance dispersal, but for many habitats, the SAC network does not support connectivity between protected patches. When interpreting the results, however, one should keep in mind that the habitat maps used in the assessment are based on modelling only, and therefore there is uncertainty in the distribution of the habitats (also see Dinesen et al. 2007).

For *estuaries,* potential for connectivity using 25km distance is found only in Sweden, but practically no connectivity between *protected estuaries* was found. The results indicate that the factor repressing connectivity of protected sites by the Swedish coast, is the low representation of the *estuaries* within SACs (8 *estuaries* and only 2.8% of their total area). Therefore more *estuaries* should be protected across the whole pilot area. On the Swedish side, where improving connectivity is possible, the sites should be placed carefully to support better connectivity.

For another relatively rare habitat, *esker islands*, potential for connectivity is found in three separate areas, but in only one of these areas the *esker islands* are protected. On the Swedish side of the pilot area and around Åland, only a few patches of *esker islands* are actually protected and therefore no connectivity within protected patches occurs. Therefore, the assessment indicates that in order to improve connectivity, more *esker islands* should be protected especially in Sweden and in Åland.

The *large shallow bays* show good potential for connectivity with 25km dispersal distance in the whole pilot area. Connectivity between protected patches, however, is only found on the Swedish side of the pilot area. On the Finnish side of the pilot area only three bays are partly protected, and only one completely – therefore it is not surprising that no connectivity between protected patches was found. To improve connectivity, more sites including *large shallow bays* should be designated, especially in Finland.

Coastal lagoons, *reefs* and *boreal Baltic islets and small islands* identified by modelling were are numerous and spread throughout the pilot area, therefore showing good potential for connectivity. For *reefs* and *boreal Baltic islets and small islands* that are both hard bottom habitats, the assessment indicates good connectivity when using 25km dispersal distance but when it comes to short distance dispersers, connected clusters of these habitats are concentrated in only few areas. Interestingly, the location of the areas of good short-distance connectivity coincides with the largest SACs in the pilot area. This result clearly demonstrates the importance of large sites in supporting connectivity of short-distance dispersers.

Some of the habitats assessed here may share some characteristics e.g. in terms of bottom substrate or exposure, and may therefore host similar species assemblages, at least to some extent (e.g. *reefs* and underwater parts of the *boreal Baltic islets and small islands).* It is therefore likely that dispersal "across" these habitats also occurs. On the contrary, *coastal lagoons* that are listed as a priority habitat in the Habitats Directive host species assemblages that are relatively unique to the lagoons, such as diverse communities of charophytes and vascular plants. Therefore, securing connectivity from one coastal lagoon to another is very important. The assessment indicates that there are some gaps even in the long-distance connectivity between protected lagoons. When using the dispersal distance of 1km, there is potential mainly for more local dispersal between smaller clusters of lagoons but possibilities for short-distance dispersal between *protected* lagoons are almost non-existent, except for some small areas in Sweden. Many of the charophytes and vascular plants, however, may spread longer distances from one area to another via birds (Figuerola & Green 2002), and floating of seeds is an important dispersal strategy and should be considered when designing new sites to improve connectivity between *coastal lagoons.*

5.5.3 Results and discussion on the fish habitat assessment

The proportion of area within the dispersal range of protected EFHs was estimated to be 23% and 15% of the potential connectivity area for the perch and pike habitats respectively (Table 18). The geographical distribution of these areas is strongly biased, with the most significant gaps particularly in the central parts of the studied area (Figures 35 A and B). The best connected areas of protected EFHs coincide to a large extent with the areas where the largest SACs in the pilot area are located. This suggests that unless relatively close to each other, large protected sites are more effective in supporting connectivity than small ones, even for species that have potential to disperse or migrate 5-10km.

Table 18. Estimation of area covered by dispersal.

	Connected area, total (ha)	**Connected area covered by protected EFH (ha)**	**Proportion of connected area covered by protected EFH (%)**
Perch spawning area	959 900	224 400	23.4
Pike nursery area	737 700	107 500	14.6

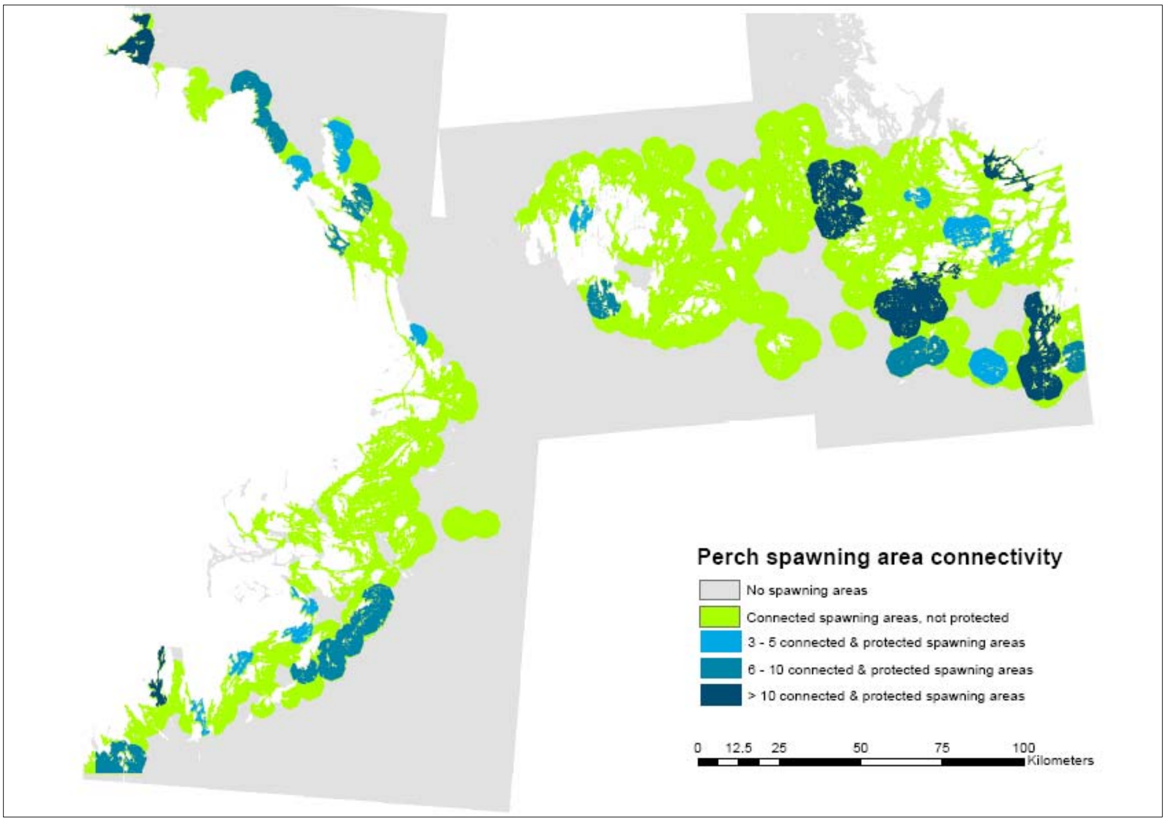
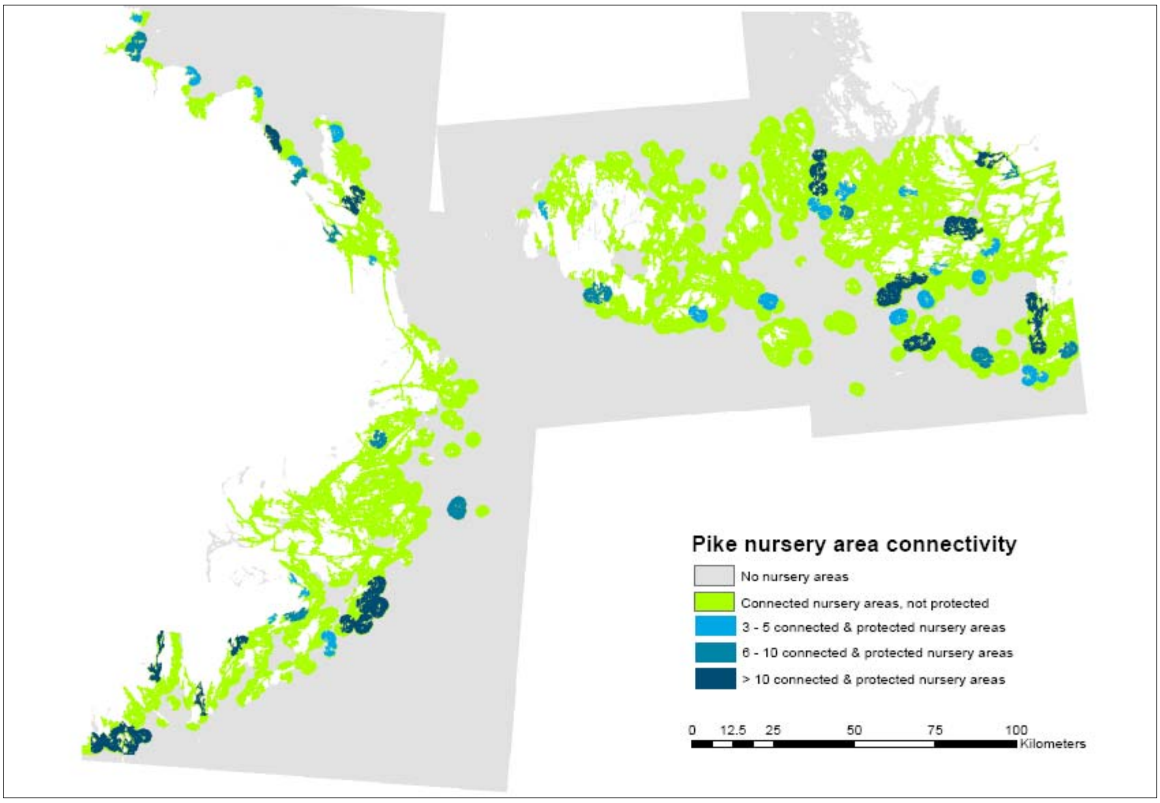


Figure 35 A. Connectivity assessment of perch spawning habitats. Coloured fields show the expected connection ranges of all identified perch spawning habitats in the pilot area. Blue areas include at least 3 interconnected and protected perch spawning habitats. Light green areas represent interconnected but unprotected perch spawning habitats. Improved protection in light green areas should be prioritized in order to support natural population exchange.



Figures 35 B. Connectivity assessment of pike nursery areas. For explanation of the assessment, see Fig. 35 A.

5.6 Conclusions and recommendations

5.6.1 Is the current Natura 2000 network providing sufficient protection to the target habitats?

In general, the assessment of ecological coherence within the pilot area showed very similar results to the assessment at the Baltic Sea scale. It can be concluded that significant improvements to the network are needed to fulfil its aims to sufficiently protect the marine Natura 2000 habitats and to become an ecologically coherent network .

The size distribution of the SACs is biased towards small areas and the inclusion of the SPAs does not improve the situation. The small sizes of the sites result in many of the larger habitats not being completely protected within the sites, which can be regarded as a major shortcoming of the sites. It should be a recommendation of the sites to cover the whole habitat it aims to protect, not only minor parts of it. The small sizes of the sites are also reflected in the results of the analyses carried out on other criteria, especially replication and connectivity.

Representation of all habitats assessed were well below the target level of 20% and of 60% for c*oastal lagoons*. The inclusion of SPAs to the network significantly increased representation only of e*stuaries,* as they are often important feeding and breeding areas for birds and therefore designated as SPAs. It should be kept in mind, however, that the SPAs do not protect the benthic habitats, unless they are important for birds. Poor representation of the Natura 2000 habitats is also reflected in the poor representation of the essential fish habitats, as the shallow vegetated habitats are often also important habitats for fish. For most studied fish species the proportion of protected recruitment habitats is actually smaller than if the Natura 2000 sites had been located randomly within the study area.

Most of the Natura 2000 habitats have many replicates within the SAC network, especially those that are generally small and numerous and cover the whole pilot area. As mentioned, however, the small sizes of the sites often result in only partial protection of the habitats and therefore many of the replicates identified by the assessment may not be large enough to support viable communities of species. For example, e*stuaries* only have eight replicates within the network and all of them, except for one, are only parts of *estuaries*, not complete habitats. The replicates are often also unevenly distributed across the pilot area, e.g. *large shallow inlets and bays* only have four protected patches in Finland, while the rest of the replicates are located by the Swedish coast.

The uneven distribution of the protected habitats is also one of the factors affecting connectivity of the habitats. For some habitats, large gaps in connectivity between protected patches were identified, even when there was good potential for connectivity and when looking at long-distance dispersal (25km). Gaps in long-distance connectivity were shown to occur for *large shallow inlets and bays* in Finland (including Åland), for *esker islands* in Sweden and in Åland and also for *coastal lagoons* in parts of the Finnish Archipelago Sea and in some areas in Åland. When looking at connectivity between protected habitats and using the 1km dispersal distance, severe gaps were found. Not all of the habitats have potential for supporting connectivity of short-distance dispersers (e.g. *estuaries*), but the protected patches of those habitats that did have potential (e.g. *reefs*, *coastal lagoons* or *boreal Baltic islets and small islands*) are generally too far from each other. The only exceptions are the areas where the largest SACs of the pilot area are located. These larger sites are able to support connectivity for short-distance disperses as well. The concentration of good connectivity areas to the areas of large SACs was also found when assessing the essential fish habitats. This further suggests the importance of larger sites to species that disperse or migrate 5-10km. Generally, the connectivity among protected recruitment habitats of assessed fish species was found to be weak.

In conclusion, the recipe to improve the ecological coherence of the Natura 2000 network is rather simple. **More large sites** should be designated and their delineation should be based on knowledge about the distribution of the marine Natura 2000 habitats. More emphasis should be set on **including whole habitats** within the sites, not only parts of them. The designation of larger sites is also essential for improving connectivity of short-distance dispersers. Overall, **representation of all habitats assessed should be increased**, particularly that of *coastal lagoons, reefs* and *estuaries.* Currently the *estuaries* are included mainly in the SPA network, which does not protect the marine biodiversity, except when concerning birds. When increasing representation of the network (i.e. increasing replicates of all habitats), emphasis should also be set on **placing the new replicates in areas where no replicates of that particular habitat occur. This would also improve connectivity between habitats.** As mentioned in the beginning of this case study, the Natura 2000 habitats are actually protected only in those sites where they are listed to occur. Based on the modelled habitats, however, many of the habitats also occurred within many other sites. Therefore, perhaps the simplest means of increasing protection of the Natura 2000 sites, is to **list all marine habitats actually occurring within the sites in the habitat lists of the sites.** More detailed data on the distribution of the habitats is also needed for this.

5.6.2 Recommendations for further assessments

This assessment of ecological coherence of the Natura 2000 network, using distribution maps of Natura 2000 habitats, is the first carried out in the Baltic Sea. As most of the assessed habitats occur only in coastal areas, the vast archipelago between Sweden and Finland with its complex coastline presented an interesting pilot area for the assessment. If/when data on distribution of the Natura 2000 habitats in the whole Baltic Sea becomes available, however, it would be informative to carry out a similar assessment on the whole Baltic Sea region.

Naturally, a fine-scale assessment of the network should include more detailed analysis tools and data than a Baltic Sea scale assessment. The background data used in this assessment was modelled habitat maps of Natura 2000 habitats and essential fish habitats. Although the maps used were based on higher resolution datasets than the marine landscape maps used in the whole Baltic Sea scale assessment, and aerial photos were used in identifying some of the habitats (Dinesen et al. 2007), there is a certain level of uncertainty as to whether the habitats actually occur where they are shown on the maps. In order to improve the background data, not only better modelling, but more importantly, groundtruthing of the models is definitely needed. In addition to extensive validation data, more ecological knowledge on these habitats is also needed. As Natura 2000 habitats are mostly geophysically defined habitat complexes that host a variety of habitats, more knowledge is needed on species occurring within these habitats, especially on key species. The Habitats Directive sets clear objectives for representation of the habitats within the network (20% and 60% for priority habitats) but in order to set more detailed goals on other criteria, adequacy or connectivity, thorough ecological knowledge on, for example, species' habitat requirements (e.g. the size of a habitat patch necessary to support viable populations or if buffer zones are needed) and dispersal distances are needed.

The methods used in this assessment are simple, but clear shortcomings of the Natura 2000 network in the pilot area were clearly identified. As more ecological data becomes available, more detailed criteria should be set and more sophisticated methods used. As with the assessment carried out at the Baltic Sea scale, a major shortcoming of the connectivity assessment was that the currents and other water movements were not considered.. In future connectivity assessments, 3D-current models should be used, preferably combined with information on species' dispersal periods. Monthly, weekly or even daily variation in water currents may significantly affect species' dispersal or even induce its beginning. Other important aspects to be considered in the assessment are, for example, data on water quality as well as socio-economical data in order to assess whether the protected areas are located in suitable sites. If possible, in a more detailed assessment some degree of site by site investigation should also be included to better assess the adequacy of the sites, e.g. to see whether the sites are suitable in size and shape to support the habitats they are protecting and whether the sites cover whole habitats or only parts of them.

As the Natura 2000 network is further developed, the assessment of its ecological coherence should be carried out repeatedly to assess whether better coherence of the network has been achieved and to give advice on how to further improve it. The assessments should preferably be done at a Baltic Sea scale, to assess the network as a whole, but even more local, regional and national assessments provide a good basis for improving the network. Although better knowledge would certainly improve the accuracy of the coherence assessment, we should not wait for perfect knowledge to take action. This assessment has shown that tools can already be found and ways to take steps forward towards a more coherent network of Natura 2000 areas can be identified.

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7 SOURCES OF DATA

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8 ANNEXES TO THE REPORT

8.1 Comparison between Natura 2000 Annex I habitats and topographic seabed and coastal physiographic landscapes

NATURA Habitat/Definition	Equivalence	BALANCE Marine Landscape
Definition	**Natura <-> ML**	**Information in context to NATURA**
1110 Sandbanks which are slightly covered by sea water all the time	**Included within**	**Mound, sand (photic)**
Sublittoral sandbanks, permanently submerged	Included	Elevations of the seafloor with sand. Elevation up to waterline not studied.
Water depth is seldom more than 20 m below Chart Datum.	Included	Landscapes occur in all depths, division into photic landscapes has been done
Non-vegetated sandbanks or sandbanks belonging to the *Zosteretum marinae* and *Cymodoceion modosae*	Not studied/Excluded	Identification on the basis of sediment, biota not examined

1130 Estuaries	**Included within**	**Estuary Landscapes**
Downstream part of a river valley, subject to the tide and extending from the limit of brackish waters.	Included	Adjacent to river (visually), however river valley not studied. Salinity less than in surrounding water area. Tide and the limit of brackish water not studied within the Baltic Sea.
River estuaries are coastal inlets where, unlike 'large shallow inlets and bays' there is generally a substantial freshwater influence.	Equals	Coastal features, salinity less than in surrounding water area
The mixing of freshwater and sea water and the reduced current flows in the shelter of the estuary lead to deposition of fine sediments, often forming extensive intertidal sand and mud flats. Where tidal currents are faster than flood tides, most sediments deposit to form a delta at the mouth of the estuary.	Not studied/Included	Classification on basis of sediment not implemented, all sediment types and topographic units included
Baltic river mouths, considered as an estuary subtype, have brackish water and no tide,	Equals	Brackish water, no tide, shallow water
with large wetland vegetation (helophytic) and luxurious aquatic vegetation in shallow water areas.	Not studied/Included	Large wetland vegetation have nor been studied

NATURA Habitat/Definition	Equivalence	BALANCE Marine Landscape
Definition	**Natura <-> ML**	**Information in context to NATURA**
1170 Reefs	**Included within**	**Mound, bedrock (photic, aphotic, deep water)**
Submarine, or exposed at low tide, rocky substrates and biogenic concretions,	Partly included	BALANCE bedrock included, biogenic concretions not studied.
which arise from the sea floor in the sublittoral zone but may extend to littoral zone where there is uninterrupted zonation of plant and animal communities.	Included	Elevation of the seafloor, all depth zones included, benthic communities not studied
These reefs generally support a zonation of benthic communities of algae and animal species including concretions, encrustations and corallogenic concretions.	Not studied/Included	Classification based on sediment and topography, benthic communities not studied

1150 Coastal lagoons	**Included within**	**Lagoons lagoon-like bays**
Lagoons are expanses of shallow coastal salt water, of varying salinity and water volume, wholly or partially separated from the sea by sand banks or shingle, or, less frequently, by rocks.	Included	Coastal features less than 5 m deep, land in min. 4 directions within 15 km radius. Entrance < 1 km, wholly separated excluded.
Salinity may vary from brackish water to hypersalinity depending on rainfall, evaporation and through the addition of fresh seawater from storms, temporary flooding of the sea in winter or tidal exchange.	Equals	"Marine" coastal features
Flads and gloes, considered a Baltic variety of lagoons, are small, usually shallow, more or less delimited water bodies still connected to the sea or have been cut off from the sea very recently by land upheaval. Characterised by well-developed reedbeds and luxuriant submerged vegetation and having several morphological and botanical development stages in the process whereby sea becomes land.	Included	Too small to be identified at present scale from other bays
Salt basins and salt ponds may also be considered as lagoons, providing they had their origin on a transformed natural old lagoon or on a saltmarsh, and are characterised by a minor impact from exploitation.	Excluded	Connection to sea has to be apparent

1650 Boreal Baltic narrow inlets	Included within	Fjord and fjord-like inlets
Long and narrow inlets in the Baltic Sea, which are separated from the surrounding sea by a sill.	Partly Included	Narrow, less than 5 km wide inlet. Form/shape equals to seabed feature trough, which has length/width>= 2:1. Existence of sill is not studied.
These inlets consist usually of soft mud.	Included	Sediments not studied.
The salinity varies depending on the freshwater contribution or the salinity value of the Baltic Sea	Not studied/Included	Salinity not studied in context. All accepted.
The low tidal range and low salinity of the Baltic Sea creates an ecology that is different from that of the North Atlantic coasts.	Not studied	Ecology not studied

8.2 Representation of the marine Natura 2000 network in the Baltic Sea

Benthic marine landscape			Total quantity (Ha)	% of total area	Total quantity in SACs (Ha)	% in SACs	Total quantity in SACs-SPAs (Ha)	% in SACs-SPAs
Substrate	**Light**	**Salinity**						
Bedrock	Euphotic	0-5psu	19294	<1	1744	9	1744	9
		5-7.5psu	318477	<1	46787	15	61689	19
		7.5-11psu	17120	<1	1008	6	1011	6
		11-18psu	4852	<1	408	8	408	8
		18-30psu	6561	<1	1806	28	1826	28
		>30psu	15231	<1	6303	41	6303	41
	Non-photic	0-5psu	10348	<1	177	2	177	2
		5-7.5psu	419027	1	40193	10	50643	12
		7.5-11psu	94040	<1	918	1	932	1
		11-18psu	228	<1	0	0	0	0
		18-30psu	3844	<1	705	18	705	18
		>30psu	68753	<1	21358	31	21361	31
Hard bottom complex	Euphotic	0-5psu	435163	1	100518	23	101098	23
		5-7.5psu	663541	2	179565	27	216366	33
		7.5-11psu	107783	<1	22682	21	46606	43
		11-18psu	221815	<1	54409	25	66777	30
		18-30psu	222752	<1	51707	23	86057	39
		>30psu	11899	<1	7295	61	7295	61
	Non-photic	0-5psu	1016432	3	46263	5	48165	5
		5-7.5psu	2318956	6	174127	8	215888	9
		7.5-11psu	532828	1	41948	8	82384	15
		11-18psu	204157	<1	38025	19	53855	26
		18-30psu	167075	<1	8143	5	11494	7
		>30psu	62690	<1	10125	16	10482	17
Sand	Euphotic	0-5psu	208761	<1	23567	11	23605	11
		5-7.5psu	444153	1	179439	40	218168	49
		7.5-11psu	341971	<1	152248	45	245512	72
		11-18psu	298951	<1	88270	30	148556	50
		18-30psu	547411	1	177797	32	325375	59
		>30psu	77587	<1	28318	36	29954	39
	Non-photic	0-5psu	555376	1	8738	2	8811	2
		5-7.5psu	2496147	6	192821	8	354333	14
		7.5-11psu	2340343	6	381453	16	636287	27
		11-18psu	446164	1	23914	5	32105	7
		18-30psu	361808	<1	16966	5	34495	10
		>30psu	242465	<1	21245	9	25668	11

Benthic marine landscape			Total quantity (Ha)	% of total area	Total quantity in SACs (Ha)	% in SACs	Total quantity in SACs-SPAs (Ha)	% in SACs-SPAs
Substrate	**Light**	**Salinity**						
Hard clay	**Euphotic**	**0-5psu**	35303	<1	728	2	912	3
		5-7.5psu	272261	<1	38241	14	57968	21
		7.5-11psu	10515	<1	1144	11	1151	11
		11-18psu	1406	<1	94	7	178	13
		18-30psu	18306	<1	1859	10	2144	12
		>30psu	6439	<1	4232	66	4232	66
	Non-photic	**0-5psu**	452654	1	1469	0	2185	0
		5-7.5psu	4431365	11	71192	2	102138	2
		7.5-11psu	2944123	7	31664	1	31965	1
		11-18psu	318192	<1	8706	3	9342	3
		18-30psu	36089	<1	1424	4	1424	4
		>30psu	98970	<1	10817	11	10818	11
Mud	**Euphotic**	**0-5psu**	109564	<1	20626	19	32326	30
		5-7.5psu	391783	1	50299	13	70788	18
		7.5-11psu	46081	<1	32827	71	33914	74
		11-18psu	71648	<1	20346	28	31302	44
		18-30psu	160655	<1	35448	22	65274	41
		>30psu	15376	<1	4422	29	4428	29
	Non-photic	**0-5psu**	1335121	3	14793	1	15378	1
		5-7.5psu	4288672	11	84145	2	124794	3
		7.5-11psu	5344163	14	28163	1	29767	1
		11-18psu	1962016	5	40918	2	57923	3
		18-30psu	541346	1	30585	6	43743	8
		>30psu	1380300	3	31209	2	36393	3

8.3 Representation of the marine Natura 2000 network and the size distribution of Natura areas in the EU Member States by the Baltic Sea

Denmark

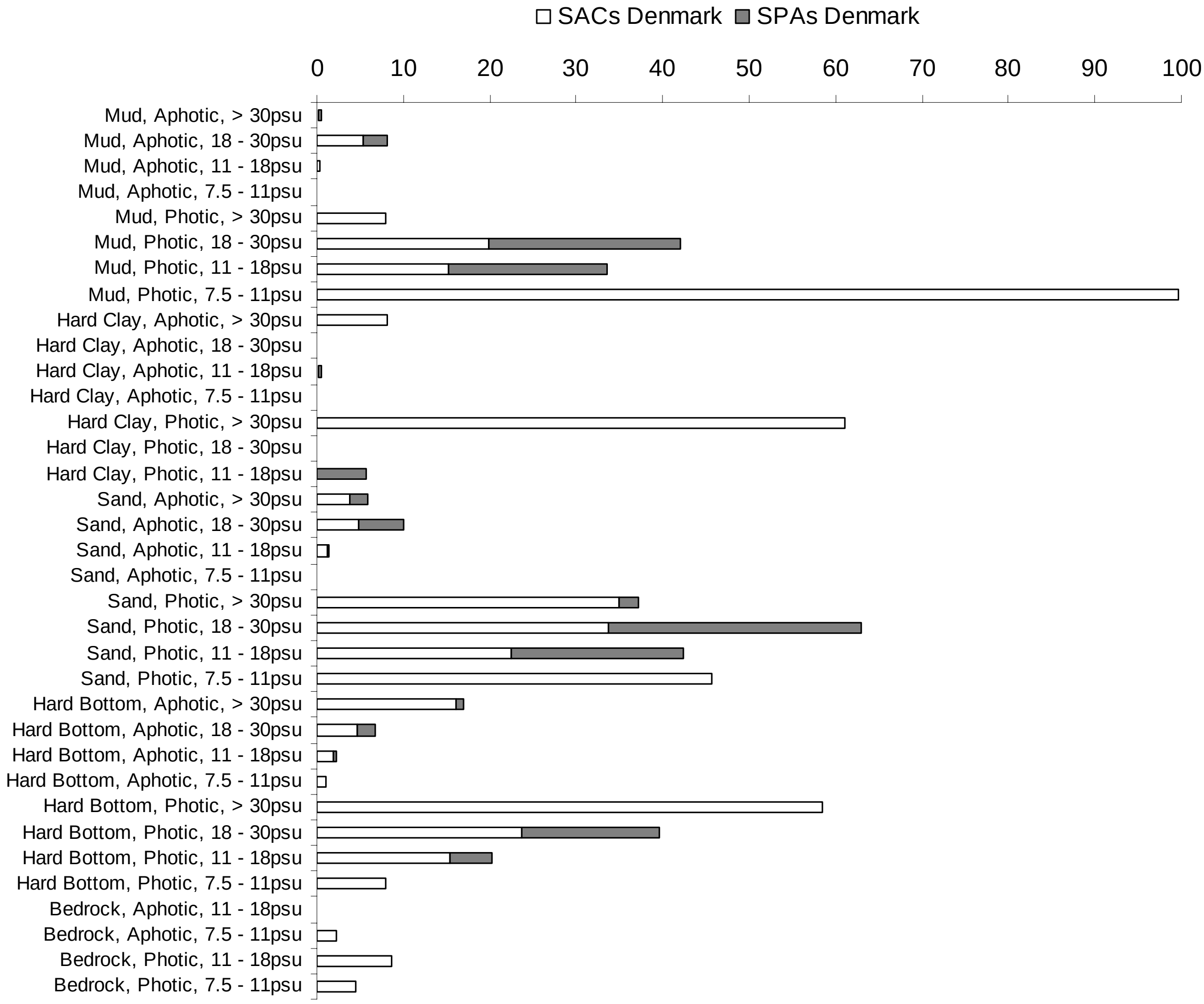


Figure 1. The area-proportion of each benthic marine landscapes within SACs (white) and within SACs+SPAs (grey) in the Danish part of the study area (incl. Kattegat and Skagerrak). Note that the amount of SPA coverage in itself cannot be read out of the graph since there is a overlap in areas between the two directives. In total 35 benthic marine landscapes occurred in the Danish area.

Estonia

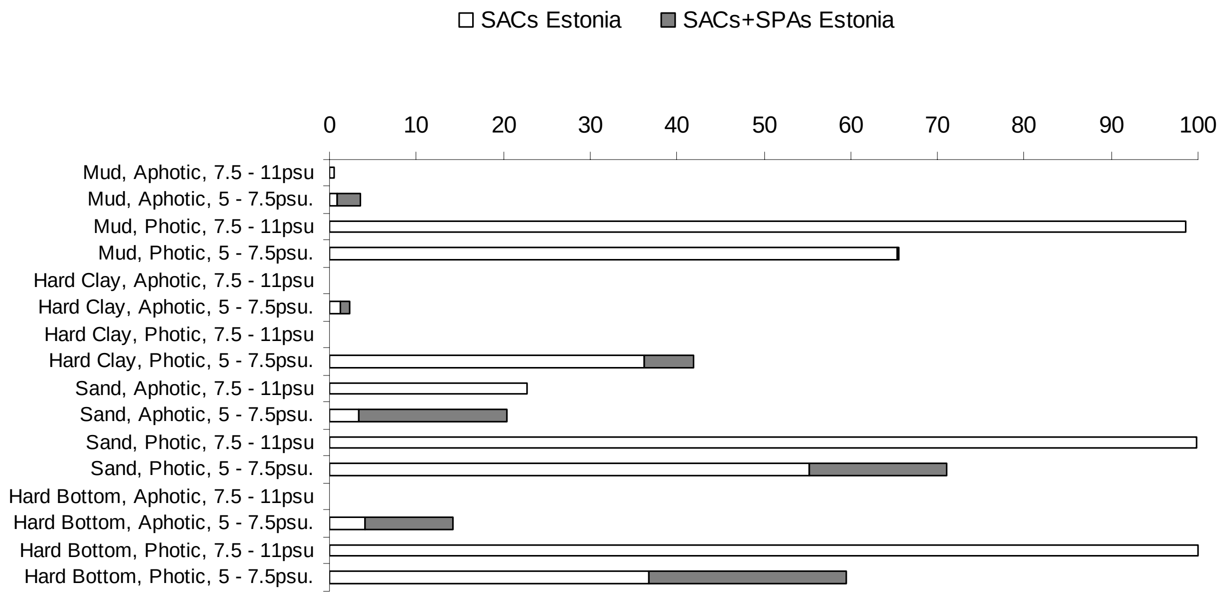


Figure 2. The area-proportion of each benthic marine landscapes within SACs (white) and within SACs+SPAs (grey) in the Estonian part of the study area. Note that the amount of SPA coverage in itself cannot be read out of the graph since there is a overlap in areas between SACs and SPAs. In total 16 benthic marine landscapes occurred in the Estonian area.

Finland

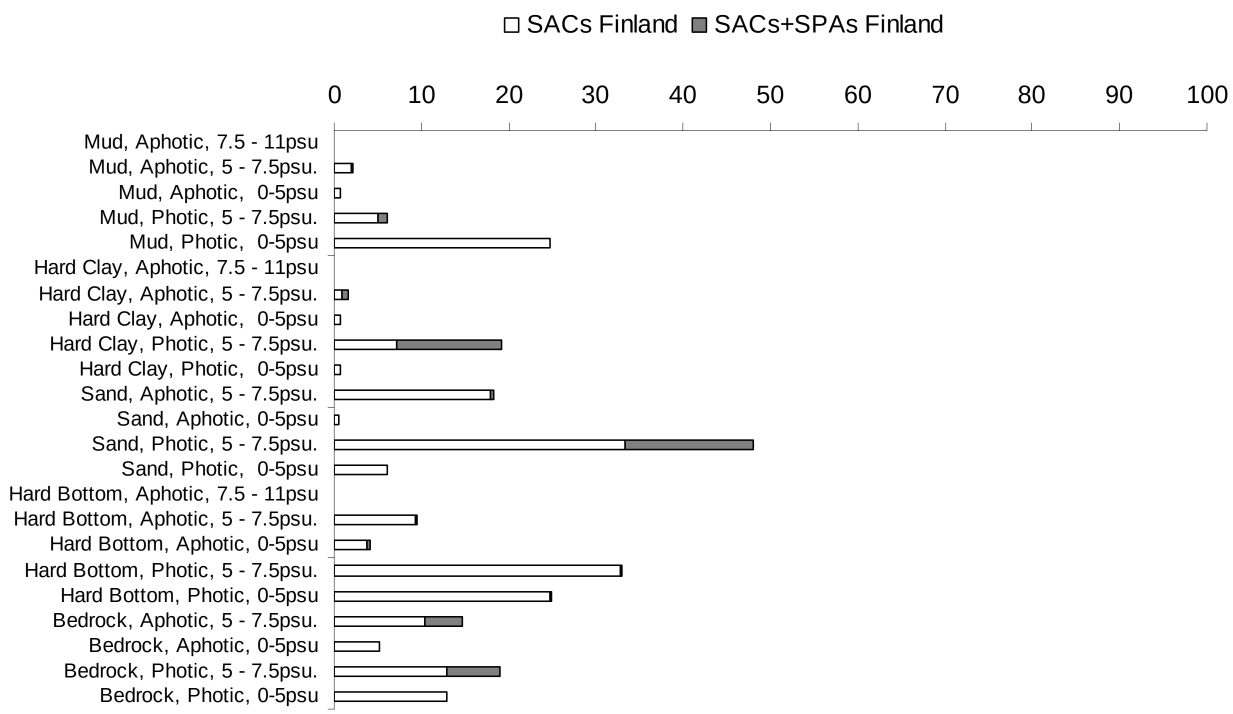


Figure 3. The area-proportion of each benthic marine landscapes within SACs (white) and within SACs+SPAs (grey) in the Finnish part of the study area. Note that the amount of SPA coverage in itself cannot be read out of the graph since there is a overlap in areas between SACs and SPAs. In total 23 benthic marine landscapes occurred in the Finnish area.

Germany

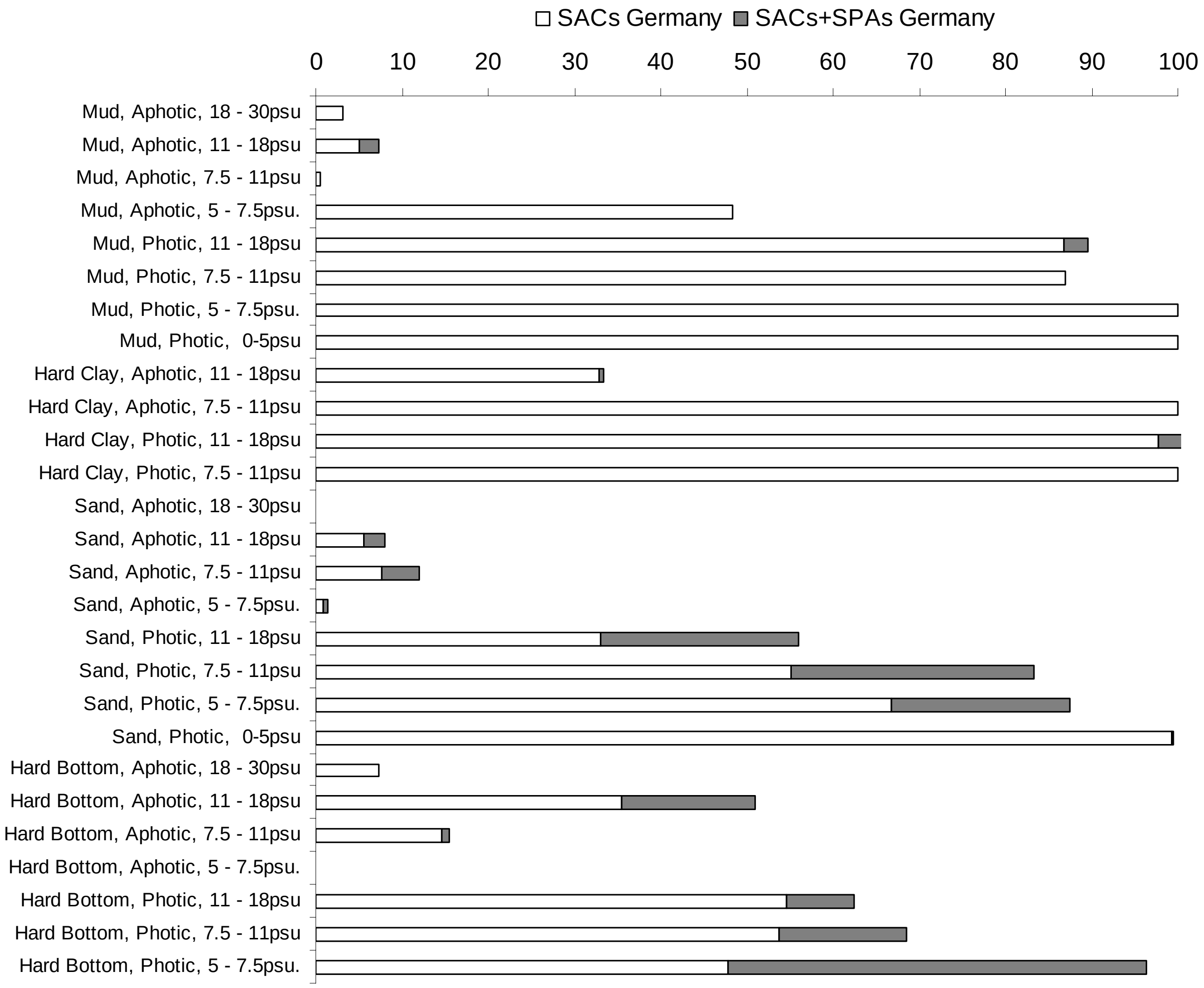


Figure 4. The area-proportion of each benthic marine landscapes within SACs (white) and within SACs+SPAs (grey) in the German part of the study area. Note that the amount of SPA coverage in itself cannot be read out of the graph since there is a overlap in areas between SACs and SPAs. In total 27 benthic marine landscapes occurred in the German area.

Latvia

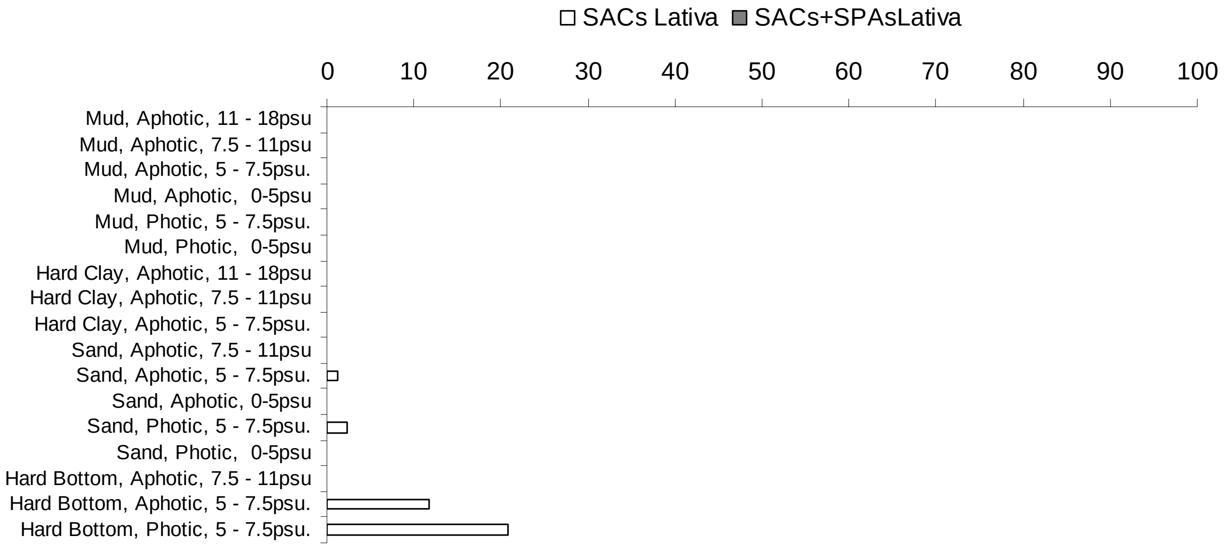


Figure 5. The area-proportion of each benthic marine landscapes within SACs (white) and within SACs+ SPAs (grey) in the Latvian part of the study area. Note that the amount of SPA coverage in itself cannot be read out of the graph since there is a overlap in areas between SACs and SPAs. In total 17 benthic marine landscapes occurred in the Latvian area.

Lithuania

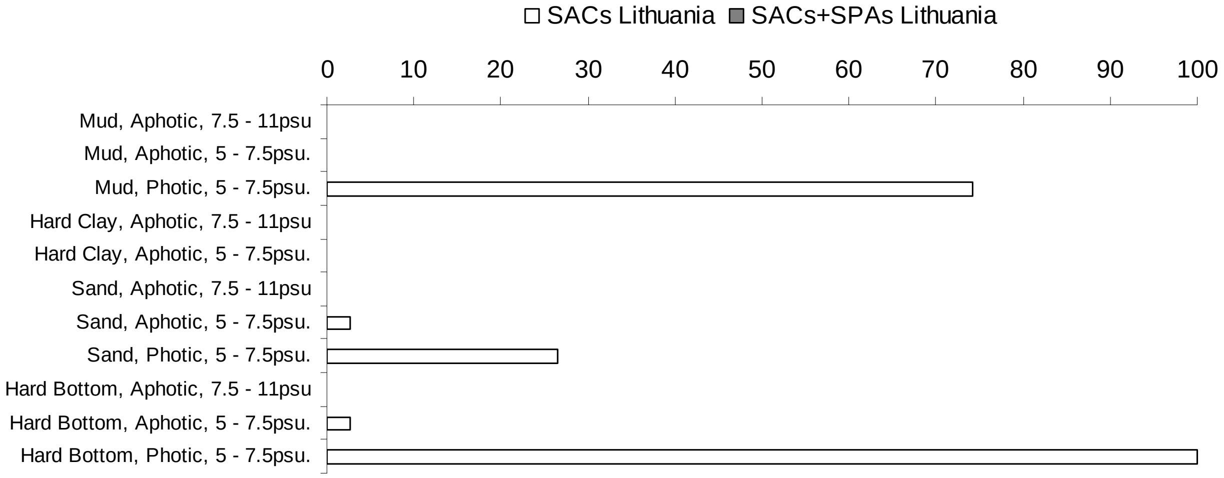


Figure 6. The area-proportion of each benthic marine landscapes within SACs (white) and within SACs+SPAs (grey) in the Lithuanian part of the study area. Note that the amount of SPA coverage in itself cannot be read out of the graph since there is a overlap in areas between SACs and SPAs. In total 11 benthic marine landscapes occurred in the LIthuanian area.

Poland

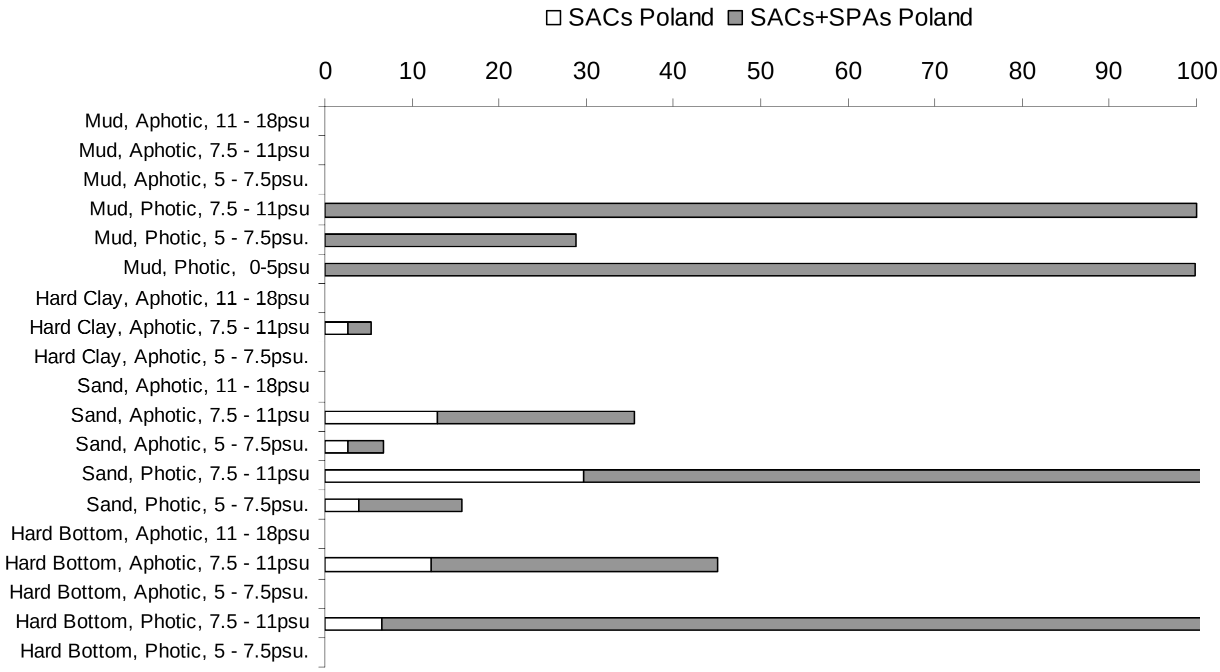


Figure 7. The area-proportion of each benthic marine landscapes within SACs (white) and within SACs+SPAs (grey) in the Polish part of the study area. Note that the amount of SPA coverage in itself cannot be read out of the graph since there is a overlap in areas between SACs and SPAs. In total 11 benthic marine landscapes occurred in the Polish area.

Sweden

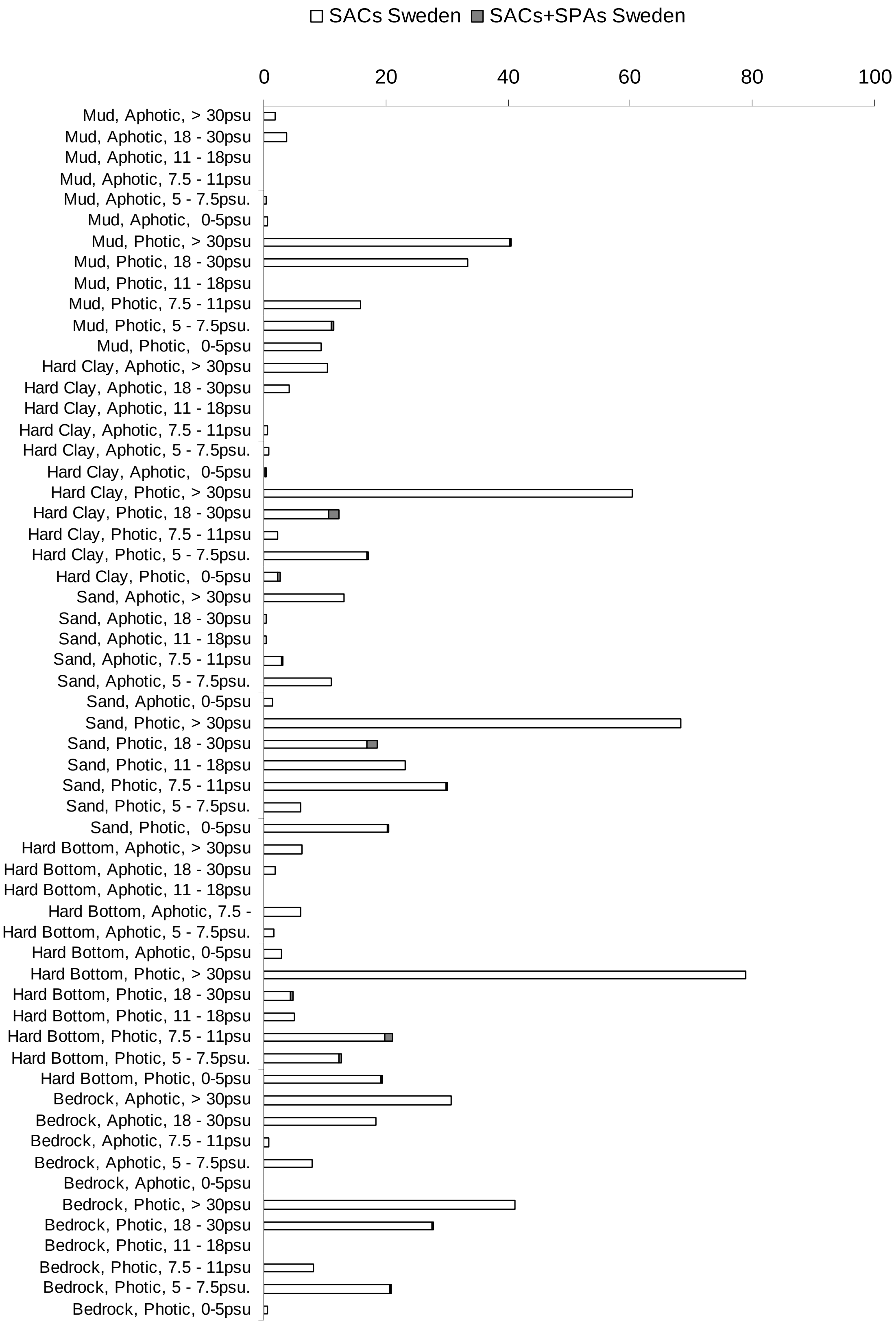
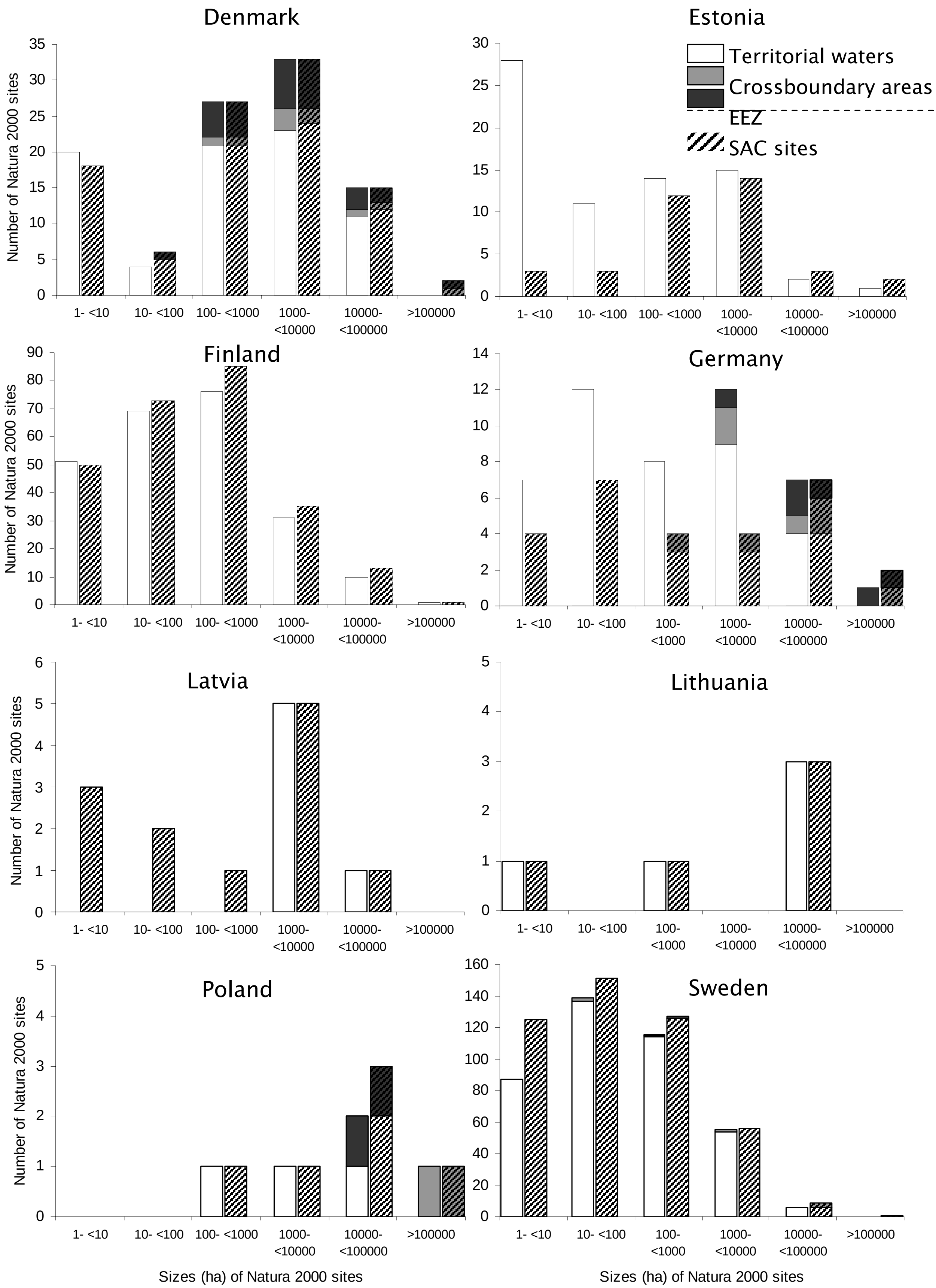


Figure 8. The area-proportion of each benthic marine landscapes within SACs (black) and within SPAs (grey) in the Swedish part of the study area. Note that the amount of SPA coverage in itself cannot be read out of the graph since there is a overlap in areas between SACs and SPAs. In total 58 benthic marine landscapes occurred in the Swedish area.

Figure 9. Size distribution of Natura 2000 sites in EU Member States in the Baltic Sea ecoregion. The sites (from 1ha to >100 000ha) are divided to those in territorial waters, those reaching over to exclusive economic zone, and those solely in the exclusive economic zone (EEZ). The graphs show the size distribution of SACs only and the combined SACs and SPAs.



8.4 Connectivity of the benthic marine landscapes within SACs using the "clusters" approach

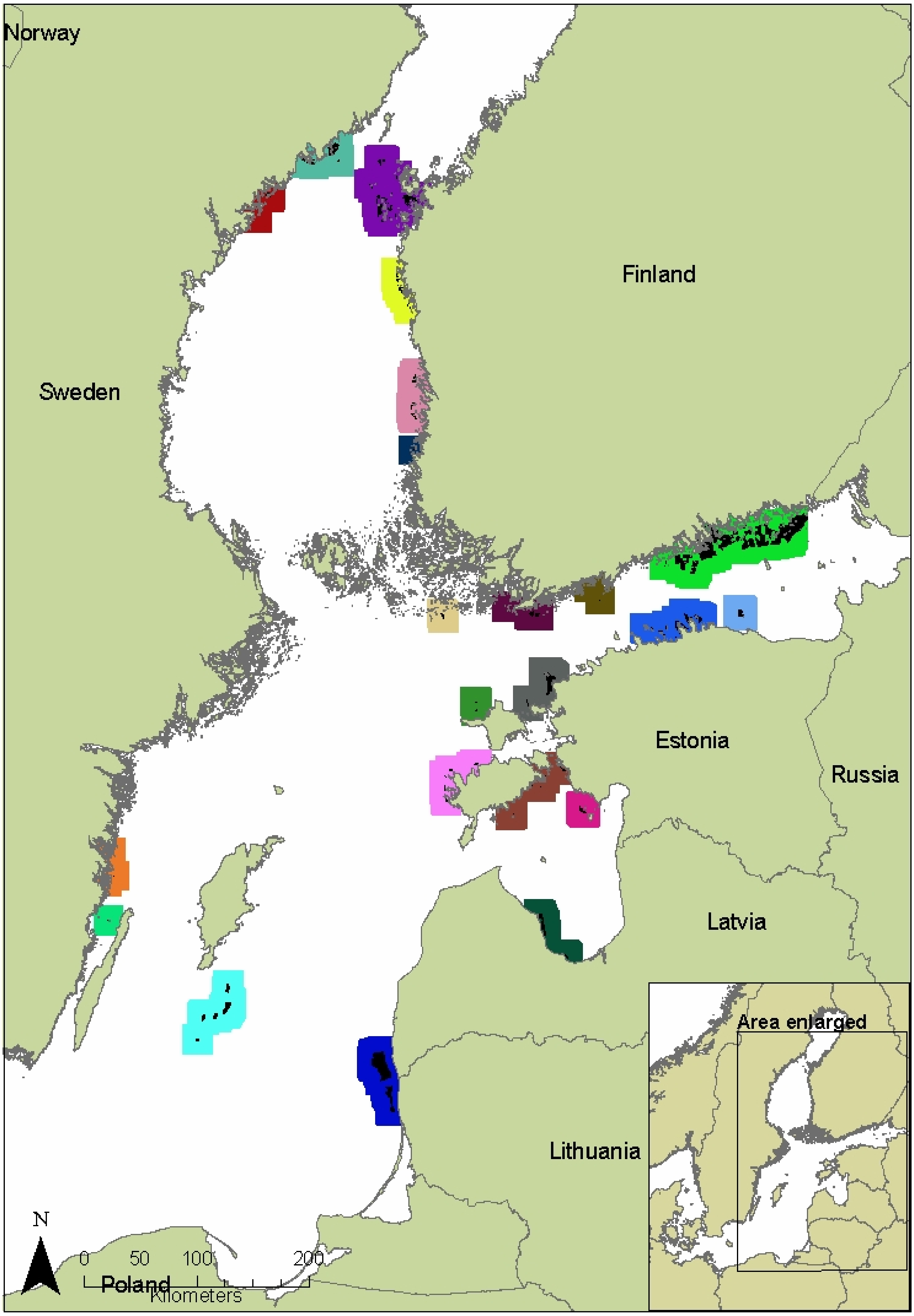


Figure 1. 22 clusters of non-photic hard bottom complex (5-7.5psu) within SACs, formed by using 25km dispersal distance. The different colours represent separate clusters.

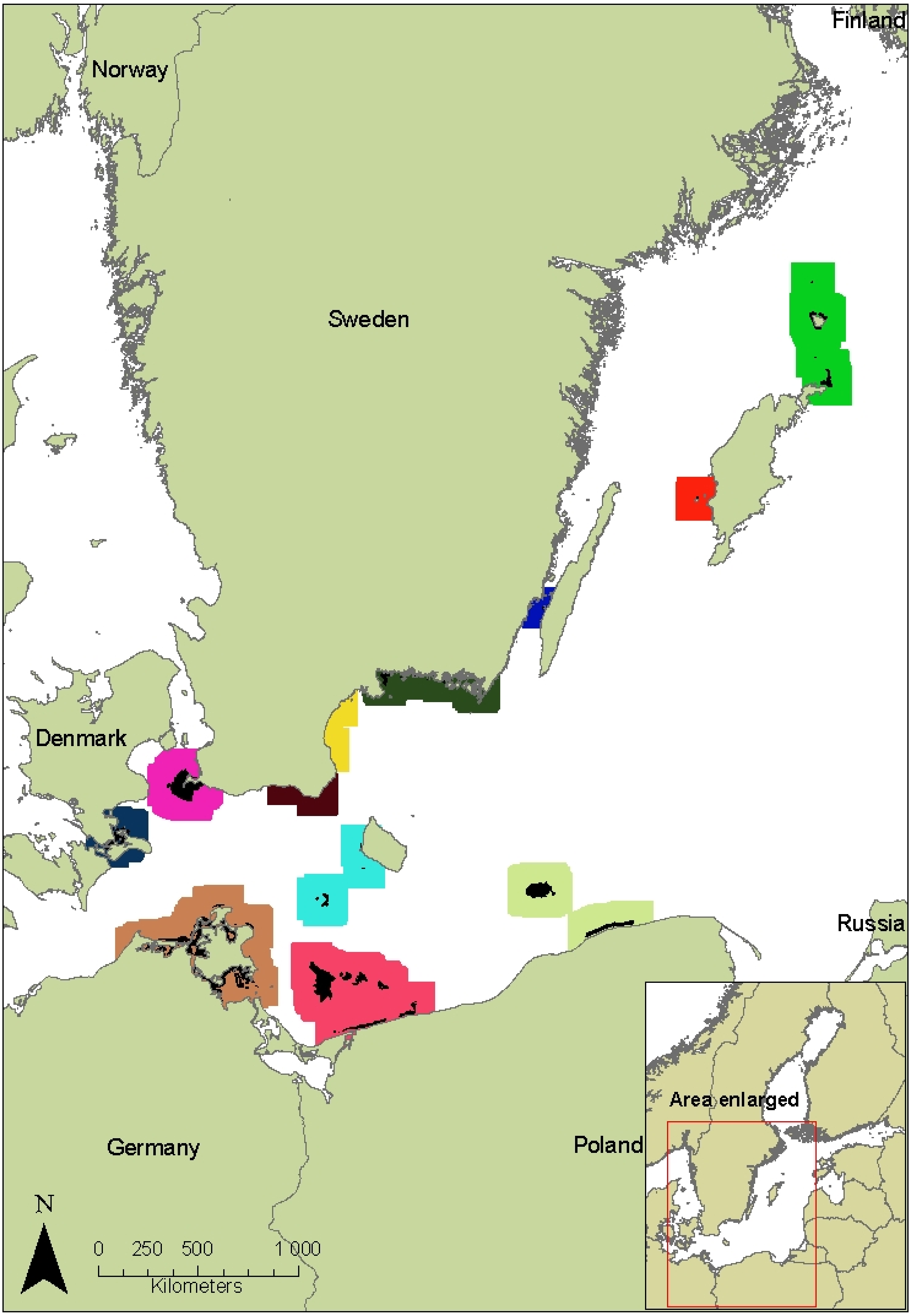


Figure 2. 13 clusters of euphotic sand (7.5-11psu) within SACs, formed by using 25km dispersal distance. The different colours represent separate clusters.

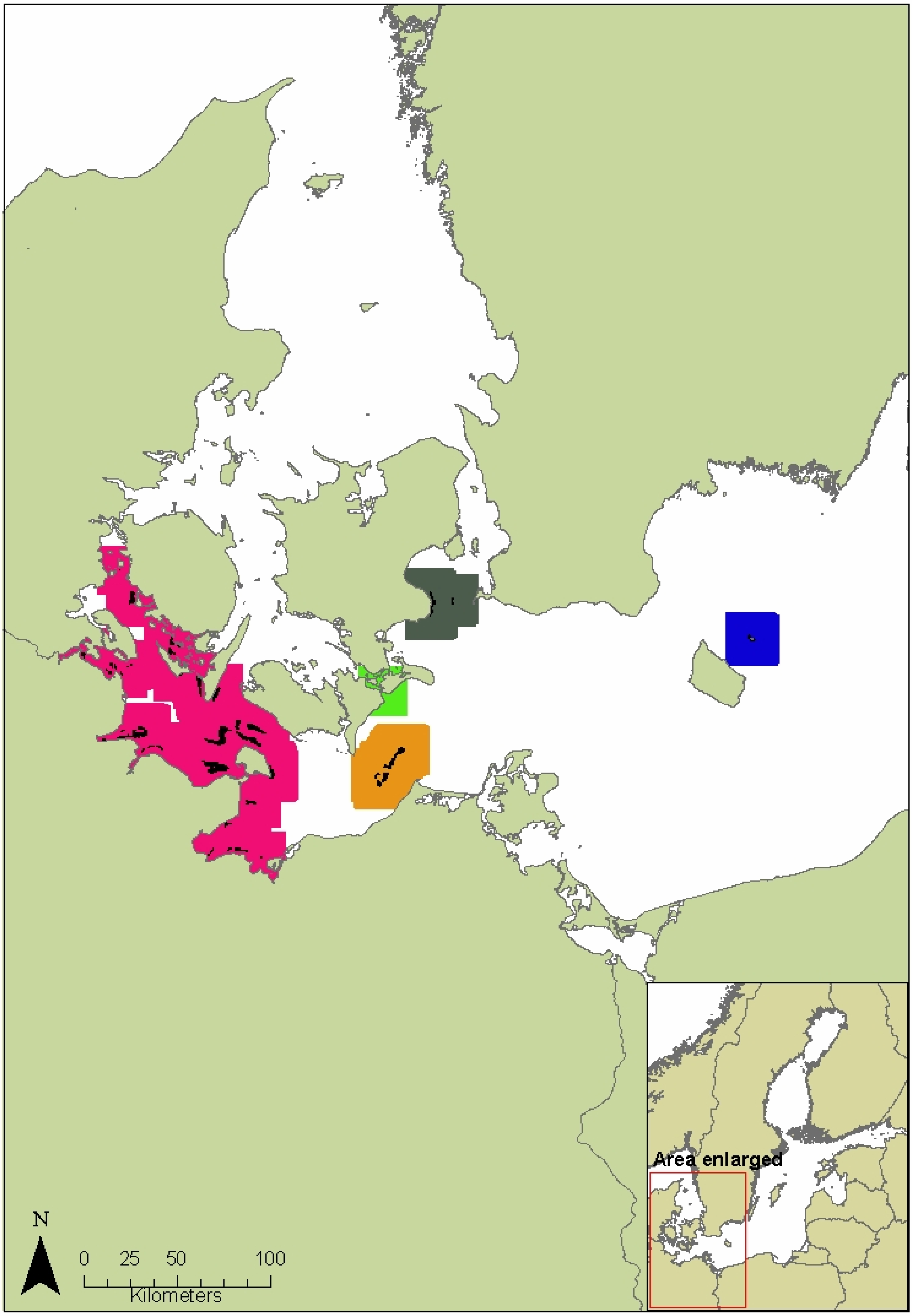


Figure 3. 5 clusters of non-photic sand (11-18psu) within SACs, formed by using 25km dispersal distance. The different colours represent separate clusters.

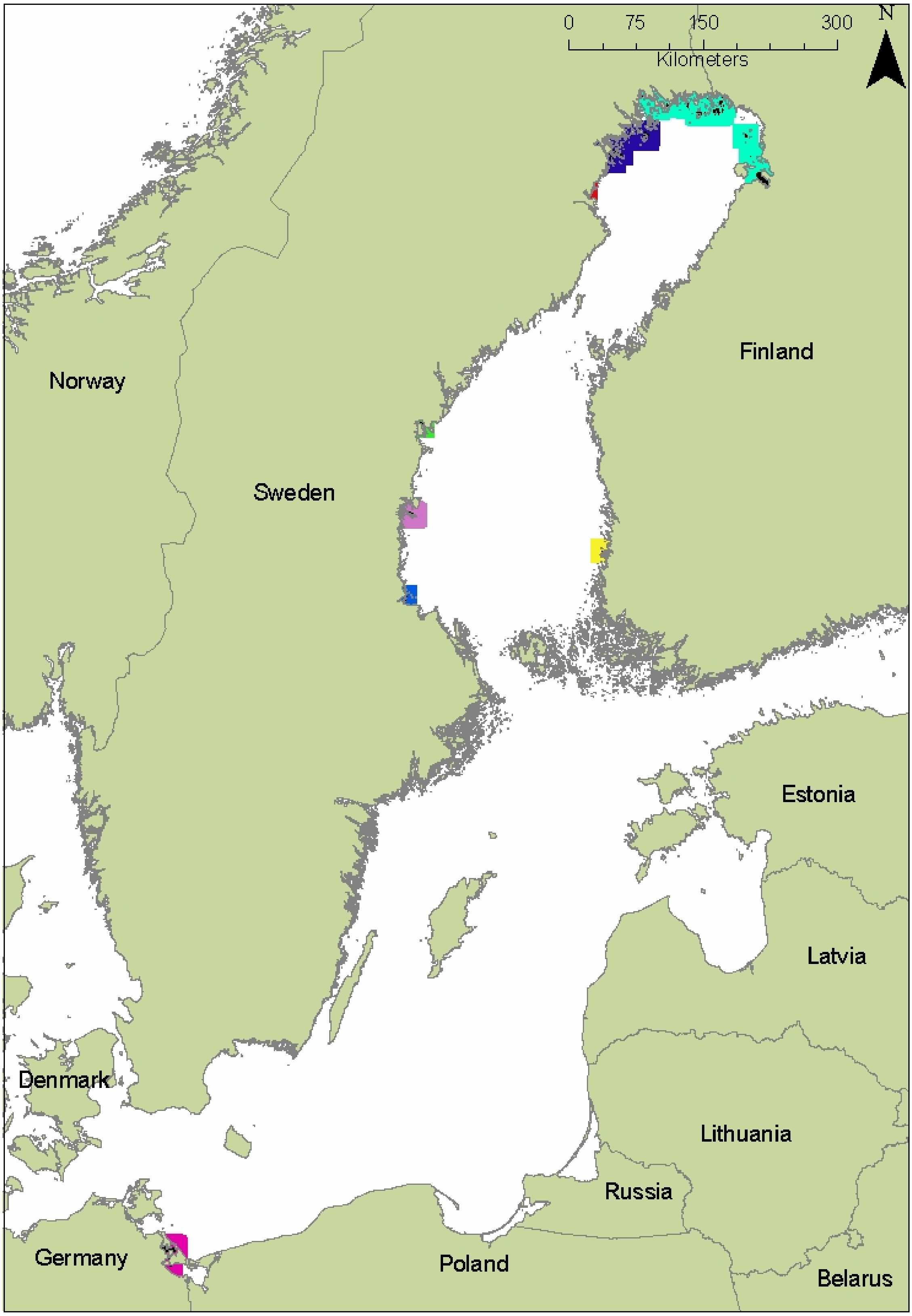


Figure 4. 8 clusters of euphotic mud (0-5psu) within SACs, formed by using 25km dispersal distance. The different colours represent separate clusters.

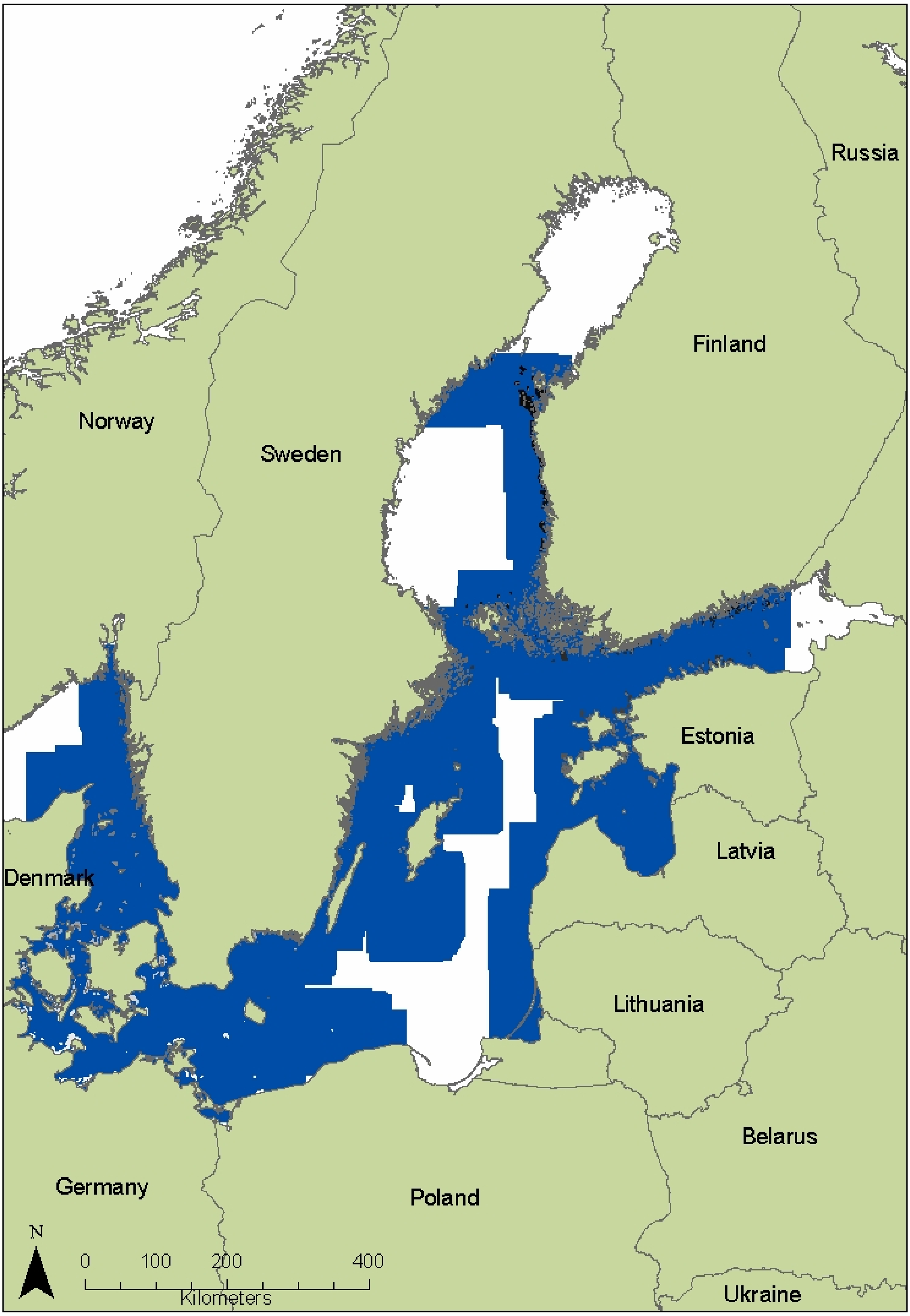


Figure 5. Only one cluster formed by benthic marine landscape patches suitable for Macoma baltica within SACs, using 100km dispersal distance.

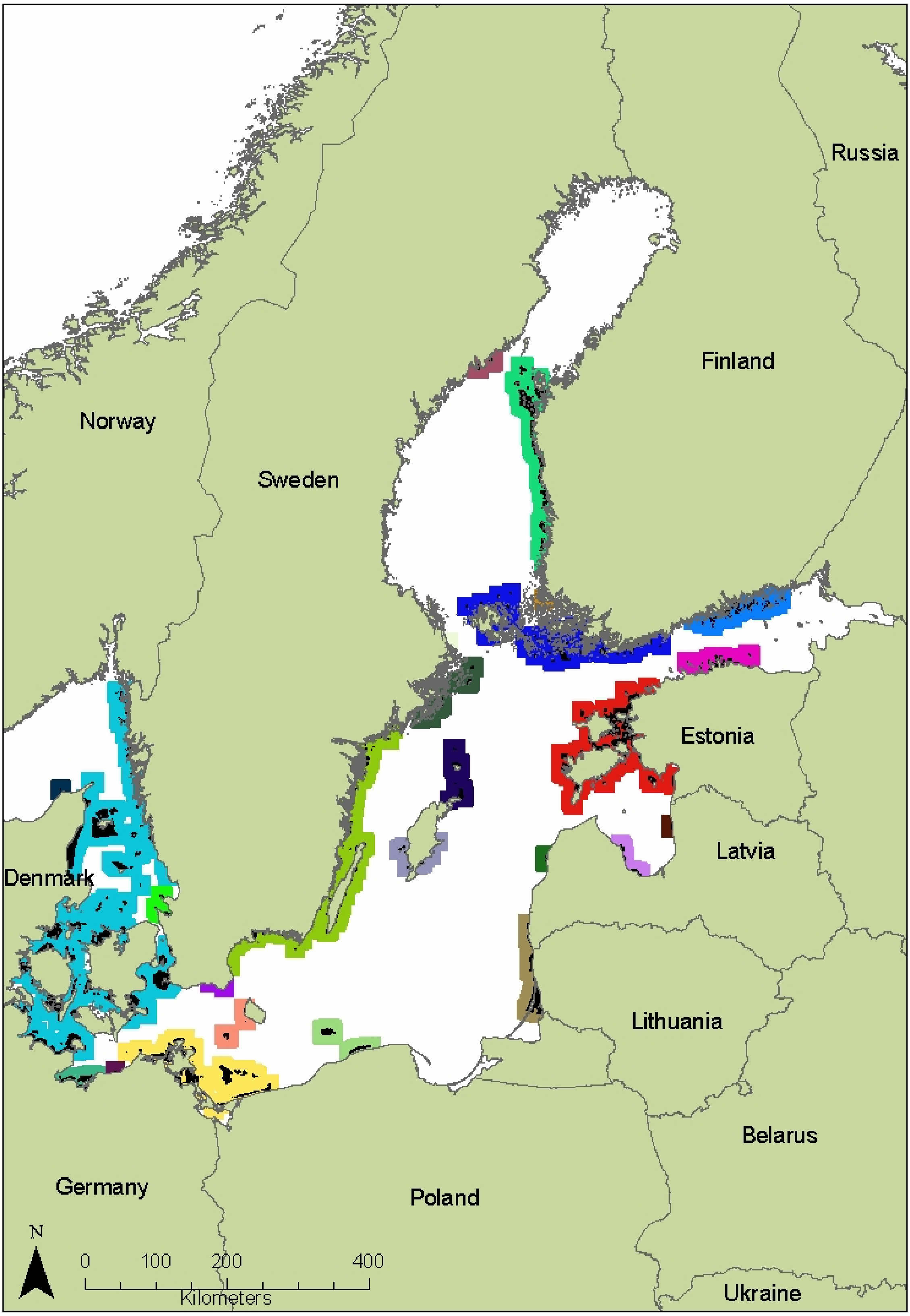


Figure 6. 25 clusters of benthic marine landscape patches suitable for Psetta maxima within SACs, formed by using 25km dispersal distance. The different colours represent separate clusters.

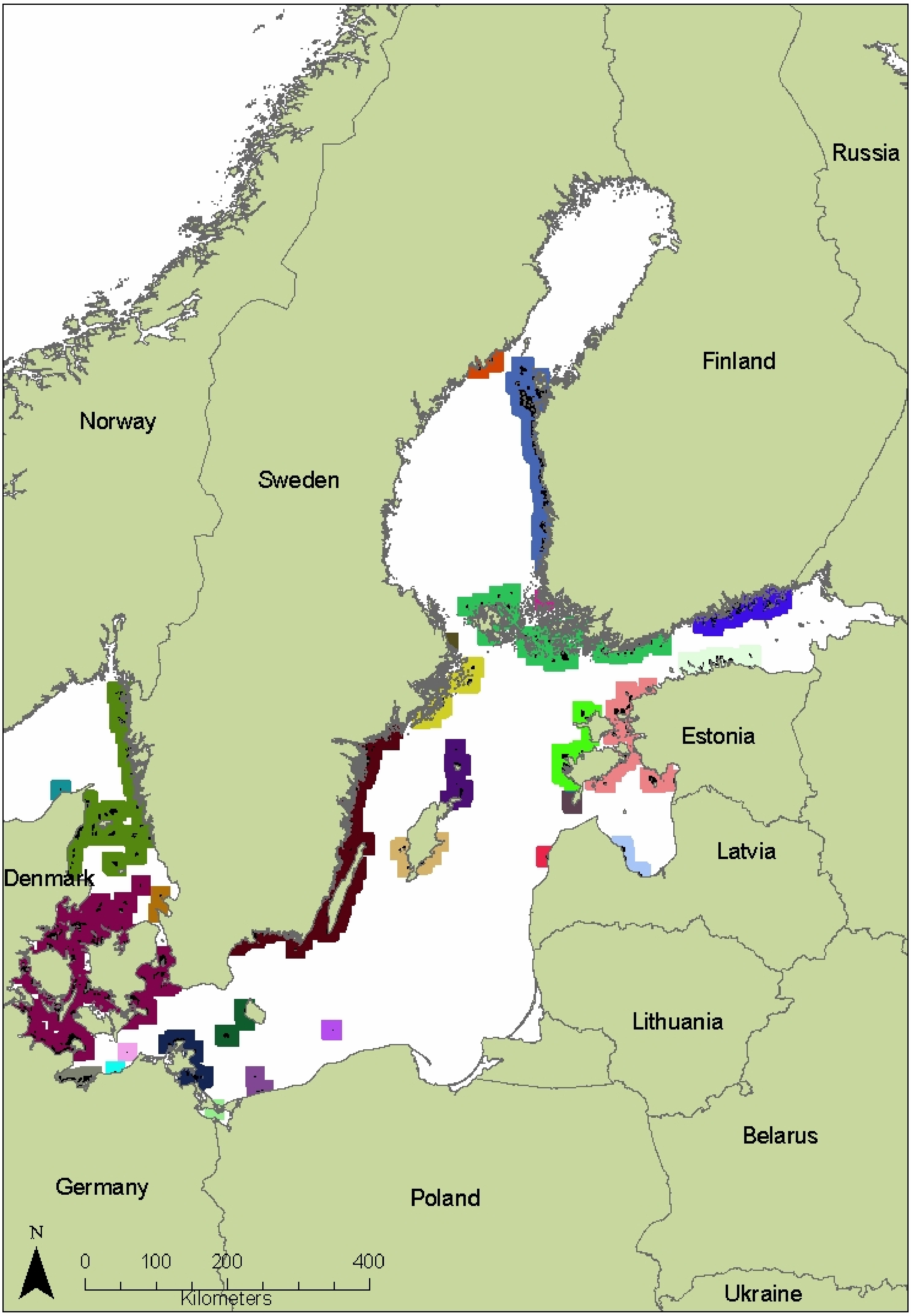


Figure 7. 28 clusters of benthic marine landscape patches suitable for Furcellaria lumbricalis and for Idotea baltica within SACs, formed by using 25km dispersal distance. The different colours represent separate clusters.

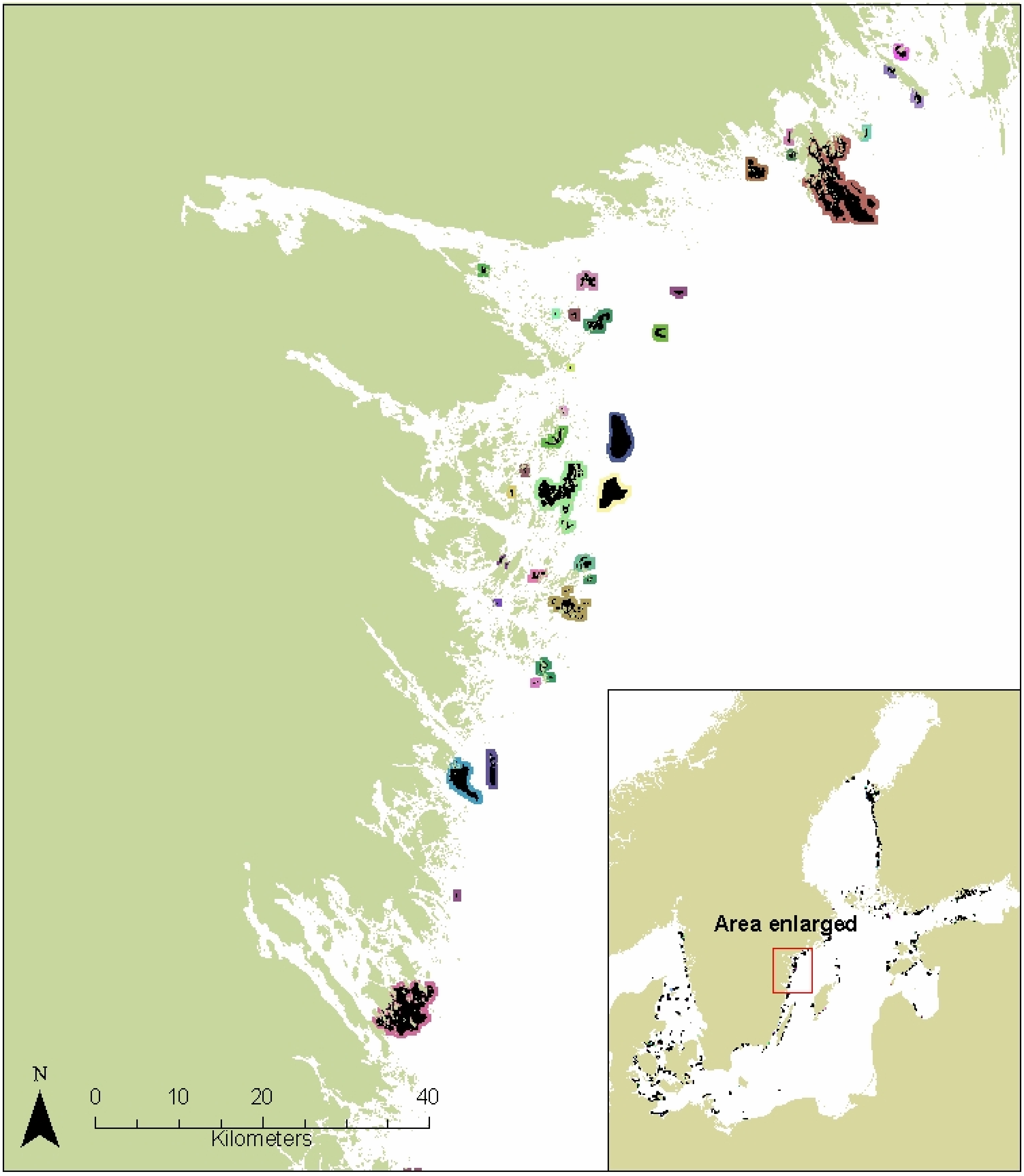


Figure 8. Clusters of benthic marine landscape patches suitable for Fucus vesiculosus within SACs, formed by using 1km dispersal distance. The index map shows the distribution of all protected patches suitable for Fucus in the Baltic Sea region and the 491 clusters they form. The larger map is a close-up from the Swedish east coast. The different colours represent separate clusters and the habitat patches are shown in black.

About the BALANCE project:

The BALANCE project aims to provide a transnational marine management template based on zoning, which can assist stakeholders in planning and implementing effective management solutions for sustainable use and protection of our valuable marine landscapes and unique natural heritage. The template will be based on data sharing, mapping of marine landscapes and habitats, development of the blue corridor concept, information on key stakeholder interests and development of a cross-sectoral and transnational Baltic zoning approach. BALANCE thus provides a transnational solution to a transnational problem.

The work is part financed by the European Union through the development fund BSR INTERREG IIIB Neighbourhood Programme and partly by the involved partners. For more information on BALANCE, please see www.balance-eu.org and for the BSR INTERREG Neighbourhood Programme, please see www.bsrinterreg.net

The **BALANCE Report Series** includes:

BALANCE Interim Report No. 1	Delineation of the BALANCE Pilot Areas
BALANCE Interim Report No. 2	Development of a methodology for selection and assessment of a representative MPA network in the Baltic Sea – an interim strategy
BALANCE Interim Report No. 3	Feasibility of hyperspectral remote sensing for mapping benthic macroalgal cover in turbid coastal waters of the Baltic Sea"
BALANCE Interim Report No. 4	Literature review of the "Blue Corridors" concept and its applicability to the Baltic Sea
BALANCE Interim Report No. 5	Evaluation of remote sensing methods as a tool to characterise shallow marine habitats I
BALANCE Interim Report No. 6	BALANCE Cruise Report – The Archipelago Sea
BALANCE Interim Report No. 7	BALANCE Cruise Report – The Kattegat
BALANCE Interim Report No. 8	BALANCE Stakeholder Communication Guide
BALANCE Interim Report No. 9	Model simulations of blue corridors in the Baltic Sea
BALANCE Interim Report No. 10	Towards marine landscapes of the Baltic Sea
BALANCE Interim Report No. 11	Fish habitat modelling in a Baltic Sea archipelago region
BALANCE Interim Report No. 12	Evaluation of remote sensing methods as a tool to characterise shallow marine habitats II
BALANCE Interim Report No. 13	Harmonizing marine geological data with the EUNIS habitat classification
BALANCE Interim Report No. 14	Intercalibration of sediment data from the Archipelago Sea
BALANCE Interim Report No. 15	Biodiversity on boulder reefs in the central Kattegat
BALANCE Interim Report No. 16	The stakeholder – nature conservation's best friend or its worst enemy?
BALANCE Interim Report No. 17	Baltic Sea oxygen maps
BALANCE Interim Report No. 18	A practical guide to Blue Corridors
BALANCE Interim Report No. 19	The BALANCE Data Portal
BALANCE Interim Report No. 20	Pelagic habitat mapping: A tool for area-based fisheries management in the Baltic Sea
BALANCE Interim Report No. 21	Mapping of marine habitats in the Kattegat
BALANCE Interim Report No. 22	E-participation as tool in planning processes
BALANCE Interim Report No. 23	The modelling of *Furcellaria lumbricalis* habitats along the Latvian coast
BALANCE Interim Report No. 24	Towards a representative MPA network in the Baltic Sea
BALANCE Interim Report No. 25	Towards ecological coherence of the MPA network in the Baltic Sea
BALANCE Interim Report No. 26	What's happening to our shores?
BALANCE Interim Report No. 27	Mapping and modelling of marine habitats in the Baltic Sea
BALANCE Interim Report No. 28	GIS tools for marine planning and management
BALANCE Interim Report No. 29	Essential fish habitats and fish migration patterns in the Northern Baltic Sea
BALANCE Interim Report No. 30	Mapping of Natura 2000 habitats in Baltic Sea archipelago areas
BALANCE Interim Report No. 31	Marine landscapes and benthic habitats in the Archipelago Sea
BALANCE Interim Report No. 32	Guidelines for harmonisation of marine data
BALANCE Interim Report No. 33	The BALANCE Conference

In addition, the above activities are summarized in four technical summary reports on the following themes: 1) Data availability and harmonisation, 2) Marine landscape and habitat mapping, 3) Ecological coherence and principles for MPA selection and design, and 4) Tools and a template for marine spatial planning. The BALANCE Synthesis Report *TOWARDS A BALTIC SEA IN BALANCE* integrates and demonstrates the key results of BALANCE and provides guidance for future marine spatial planning.