

Ecological coherence and principles for MPA assessment, selection and design

BALANCE Technical Summary Report 3/4



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Ecological coherence and principles for MPA assessment, selection and design				
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0 EXECUTIVE SUMMARY

Activities of BSR INTERREG IIIB part-financed “BALANCE” project has focused its efforts on developing tools for assessment and establishment of an ecologically coherent network of marine protected areas (MPAs) in the Baltic Sea, Kattegat and Skagerrak – a sea area shared by 10 countries. The aim has been to identify gaps in the existing network and propose tools which can be used to improve several aspects of the network, especially its biodiversity representativeness and connectivity. The work has mainly been done on a regional level where the focus has been on broad scale ecological coherence, with the exception of a few case studies where assessments have been done at a finer scale in local pilot areas, in particular in Stockholm Archipelago-Åland-Archipelago Sea.

The assessment of *ecological coherence* of the Baltic Sea MPA network (primarily the Natura 2000 network as designated under the EC Habitats Directive and Birds Directive) was done using four criteria: representativeness, adequacy, connectivity and replication. The assessment was done using ecological relevant information, GIS and statistical analyses of geographical data. The assessment showed that there are major gaps in the existing Natura 2000 network and it is not ecologically coherent. None of the four criteria for ecological coherence were fulfilled.

Using the decision support tool MARXAN we have formulated scenarios on how to *improve the representativeness* of the existing network using a regional, transparent, repeatable and objective approach. The scenarios presented were developed with the aim of demonstrating a systematic approach to selecting sites which represent the broad scale variation in the Baltic Sea, while taking into account socio-economic interests and existing MPAs. By selecting additional sites to the existing Natura 2000 SAC-network, we concluded that the area of the sites needed to fulfil the representation target corresponded to approximately 30 percent of the entire Baltic Sea water surface. The spatial positioning of sites, however, appears to be highly flexible.

We have also shown how *connectivity* of a network can be assessed and planned for, using existing ecological data on habitat preferences and migration, or by using data on larval duration combined with oceanographic data through modelling.

This work shows that it is possible to take a regional, broad scale systematic approach to assessing and designing an ecological coherent network of MPAs in the Baltic Sea and Kattegat. There is still a lack of clearly formulated conservation objectives for MPA networks, sufficient data coverage and ecological knowledge, but rather than waiting for complete knowledge we should use what is available. As long as there are obvious gaps in the network, even rather crude methods can aid us in acting on current knowledge. The methods have to be developed in parallel to the network itself.

We hope that this report will inspire governments, managers and stakeholders to participate in a regional systematic approach to designing an ecologically coherent network of MPAs in the Baltic Sea, thus further promoting a long-term sustainable development in the region.

1 INTRODUCTION

The Baltic Sea is subject to severe environmental degradation as a result of commercial and non-commercial activities such as dredging, fisheries, tourism, coastal development and land-based pollution. This is to some extent a result of a lack of regional coordination and informed planning and management of the marine environment, which in part is directly related to a lack of trans-national maps and effective tools for planning. The BALANCE project has focused its efforts on harmonizing existing data and developing efficient tools for spatial planning and management of the human activities in the Baltic Sea, tools which can be used by agencies in the region to better plan for, manage and protect the coastal and marine environment.

There are several international obligations (e.g. *World Summit for Sustainable Development and the Convention on Biological Diversity*) and regional political frameworks (e.g. *the EC Birds- and Habitats Directive and the HELCOM recommendation on Baltic Sea Protected Areas*) that require the establishment of ecological coherent networks of protected areas in the Baltic Sea region. Despite this, the term ecological coherence has still not been formally defined and most protected areas are still established site by site with little consideration of the coherence of the network they are intended to contribute to.

Part of the aim of the BALANCE project has been to develop tools for assessment and establishment of networks of marine protected areas (MPAs) in the Baltic Sea (primarily the Natura 2000 network). This report briefly summarizes the three main outputs from the activities related to assessment and establishment of ecological coherent MPA networks in a multinational context. The first chapter is an assessment of the ecological coherence of the existing Natura 2000 network, followed by two chapters that suggest frameworks and methods which can be used to improve two of the aspects of the existing networks ecological coherence. This includes; modelling of blue corridors, a stepwise decision-making process for improvements in the existing networks connectivity and methods for selecting additional sites that fill the gaps in existing networks representativeness.

The work has mainly been done on a regional level where the focus has been on broad scale ecological coherence in the entire Baltic Sea. A few case studies were carried out in pilot areas, in particular in Stockholm Archipelago-Åland-Archipelago Sea e.g. an assessment of ecological coherence at a habitat scale.

The approach and methods for designing and assessing MPA networks in the Baltic Sea developed within BALANCE can contribute to a more systematic and efficient network design and thereby a successful implementation of the above mentioned obligations.

This report summarizes most of the work done within BALANCE Work Package 3, the more interested reader can refer to the more detailed BALANCE interim reports listed at the back.

2 ASSESSING ECOLOGICAL COHERENCE

An ecological 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 such as eutrophication, invasive species or climate change.

How is an ecologically coherent network defined? The term ecological coherence has not been formally defined although it is a concept frequently referred to e.g. in the EC Habitats Directive (1992) and the OSPAR and HELCOM declarations. In this work we have followed 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. (English Nature Research Report No 686, 2006). These criteria have also been adopted by HELCOM (HELCOM HABITAT 8 2006).

Definition of ecological coherence used in the BALANCE project:

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.

In summary, the MPA network should be designed to ensure resilience and ecological functioning of an ecosystem, i.e. the aim should be to keep the natural state or "balance" of the ecosystem as a whole.

2.1 Criteria for the assessment

A literature review of scientific articles and reports as well as recommendations and guidelines set by regional bodies clearly showed that an ecologically coherent network of MPAs can be achieved by fulfilling four "universal" criteria (BALANCE Interim Report no 25): 1) Adequacy, 2) Representativeness, 3) Replication and 4) Connectivity. These criteria can also be used to assess ecological coherence of the existing networks.

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 (pelagic vs. coastal) are important considerations when assessing adequacy of a site.

Representativeness. The full range of species, habitats, landscapes and ecological processes present within a sea area should be adequately represented within the MPA network. The conservation features; populations and meta-populations of species, their habitats, the different biotopes and landscapes of the region as well as ecological processes, are hereafter referred to as **features**. 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 in 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, 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 dispersal and migration of species within and between MPAs. Evaluating connectivity is somewhat problematic as the network aims to protect a wide range of species which have highly different ranges of dispersal and mobility, both between species and at different stages in their life. 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. The network design should also take into account different life history stages of species.

In order to make these criteria practical, we need to ask questions such as which are the features we want to protect, how much of each feature should be protected, how big must the protected patch be and how far from each other should the protected sites be?



Fucus vesiculosus, the dominating submerged brown seaweed in the Baltic Sea. Photo: The Natural Heritage Service, Finland.

Zostera marina, the dominating seagrass in the Baltic Sea. Photo: The National Environmental Research Institute.

2.2 Assessment of ecological coherence

The aim of the assessment of ecological coherence within BALANCE was to (1) explore the concept of ecological coherence in the Baltic Sea regional context, (2) present measurable criteria for ecological coherence in the area, (3) develop a first set of tools that can be used repeatedly to assess ecological coherence of the Baltic Sea MPA networks, (4) present results of the preliminary assessment carried out on current Baltic Sea MPA networks (the Natura 2000 network and the HELCOM Baltic Sea Protected Areas network) and (5) to give recommendations for further work. The complete assessment with technical details is presented in BALANCE Interim Report no 25. Here, we briefly present the assessment methodology and summarise the results of the coherence assessment carried out for the Natura 2000 network in the Baltic Sea.

The Natura 2000 network consists of Special Areas of Conservation (SACs), designated under the EC Habitats Directive and Special Protection Areas (SPAs) designated under the EC Birds Directive (see Figure 1). The SACs aim at protecting habitats listed in the Annex I of the Habitats Directive and species listed in the Annexes II and IV. The 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 populations of these species. The Habitats Directive allows many human activities within the sites; as far as the activities will not endanger the values for which the site was chosen. The primary focus of this assessment was on SACs, while each analysis also included a component where the SPAs have been considered in addition to the SACs. The reason for this two-step approach is that the protection of the sites designated under the Birds Directive could be increased by designating the SPA sites also as SACs. This is probably easier than identifying and designating new unprotected sites. All Natura 2000 sites that have a marine component were included in the analysis, but only their underwater parts.

2.2.1 Methodology –principles and practical criteria

The assessment of ecological coherence was carried out in the Baltic Sea region, which was defined as including the Baltic Sea, Kattegat and parts of Skagerrak, while the Russian territorial waters and exclusive economic zone were excluded (as Russia is not an EU member and thus there are no Natura 2000 sites in Russian waters). The assessment was done on two scales: 1) on a broad scale in the entire Baltic Sea and 2) on a more detailed scale in a pilot area; the Swedish archipelago - Åland Sea - Archipelago Sea. The pilot area case study is briefly presented in Box 1. Detailed methodologies of these assessments are presented in BALANCE Interim Report no 25.

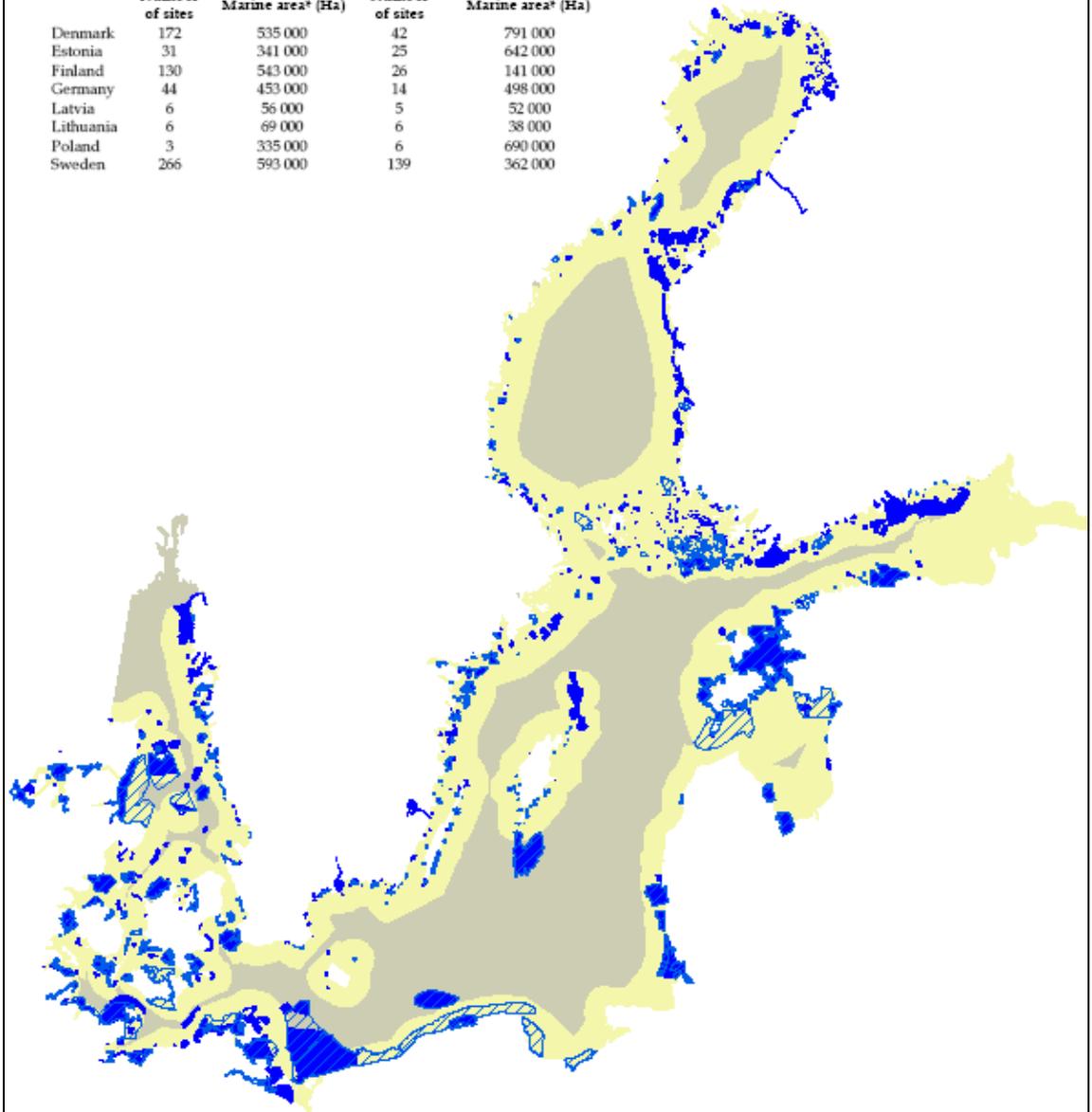
The assessment of ecological coherence at the Baltic Sea scale was based on benthic marine landscape maps developed by the BALANCE project (BALANCE Interim Report no 10). In the absence of continuous habitat maps at the Baltic Sea scale, the marine landscapes may act as proxies that capture the broad scale distribution and extent of ecologically relevant entities of the

seafloor. The benthic marine landscapes were defined by combinations of three variables: bottom substrate (5 categories), depth/available light (photic or non-photic zone) and salinity (6 categories). This resulted in 60 landscape types in total, after applying all unique combinations of categories possible (Figure 2, see BALANCE Interim Report no 10 for details). To measure ecological coherence, the four criteria of ecological coherence were translated into measurable units. The criteria applied and their motivations are discussed further in the BALANCE Interim Report no 25. In summary, *adequacy* of the Natura 2000 network was measured as the size distribution of SAC sites and of SAC+SPA sites. This approach was used to reveal major biases and gaps in the size distribution of the sites in the network, as a site by site approach to assessing adequacy was not possible at such a large scale. *Geographical representation* of the network was assessed by looking at the distribution of the sites between territorial waters (coastal areas) and exclusive economic zones (offshore areas), between six major sub-regions of the Baltic Sea. The distribution of sites across the separate Member States was also considered. *Representation of the benthic marine landscapes* within the Natura 2000 network was assessed by calculating the proportion of each landscape occurring within the network and categorizing the observed level of protection to either bad (<10%), poor (10-20%), moderate (20-30%), good (30-60%) or high (>60%) representation. A guiding principle of 20 percent was set for adequate representation. *Replication* of protected landscape patches was assessed by looking at the number of protected patches over 24 ha in size (6 pixels) of each landscape. No fixed numerical definition of what is “good replication” was set, however, a low number indicates bad replication. *Connectivity* was assessed using two approaches. 1) In a theoretical approach, five benthic marine landscape types were chosen as examples for the assessment. Protected patches of these landscapes were classified based on how many connections they had to other similar patches when using a 25 km theoretical dispersal distance. The number of isolated groups of connected and protected landscape patches was also assessed. 2) In a species-specific approach, all protected landscape patches preferred by 5 selected species were included in the analyses. Species-specific distances for these species, ranging from 1 km to 100 km were used to assess connectivity between these patches.

All analyses were carried out using relatively simple GIS analysis methods.

THE BALTIC SEA NATURA 2000 NETWORK

	Special Areas of Conservation		Special Protection Areas	
	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



 Special Protection Areas (SPA)
 Special Areas of Conservation (SAC)

 Territorial Water
 Exclusive Economic Zone



Data extracted from national databases: Denmark Nov -06, Estonia May -06, Finland-Åland May -06, Germany Nov -06, Latvia June -06, Lithuania May -06, Poland Nov -06, Sweden Jan -07

0 30 60 120 Km

* Due to the coarse resolution of the coastline data, there might be inaccuracies in the figures.

Figure 1. Natura 2000 Special Areas of Conservation (SACs) and Special Protected Areas (SPAs) in the Baltic Sea.

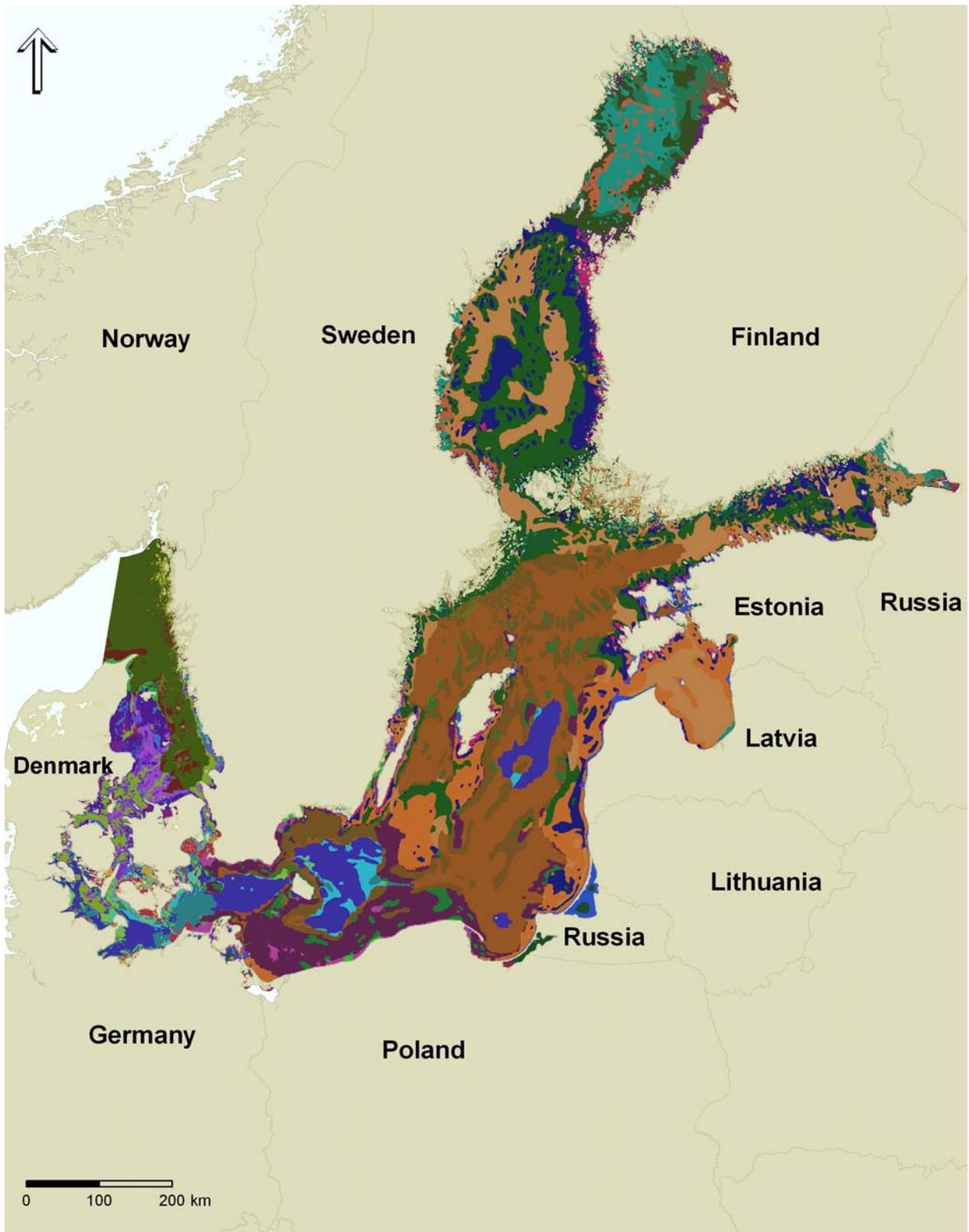


Figure 2. Benthic marine landscapes of the Baltic Sea.

2.2.2 Results and Discussion

The marine Natura 2000 network of Special Areas of Conservation (SACs) in the Baltic Sea is not ecologically coherent, given the criteria and methods used within the BALANCE project.

Adequacy; the SAC network was found to be dominated by small sites that are less than 100 ha in size (Figure 3). This is well below any recommendation for MPA size given in the scientific literature. Although SPAs are commonly larger, including them in the assessment only slightly changed the pattern. Generally, sites in the EEZ are larger than sites in the territorial waters.

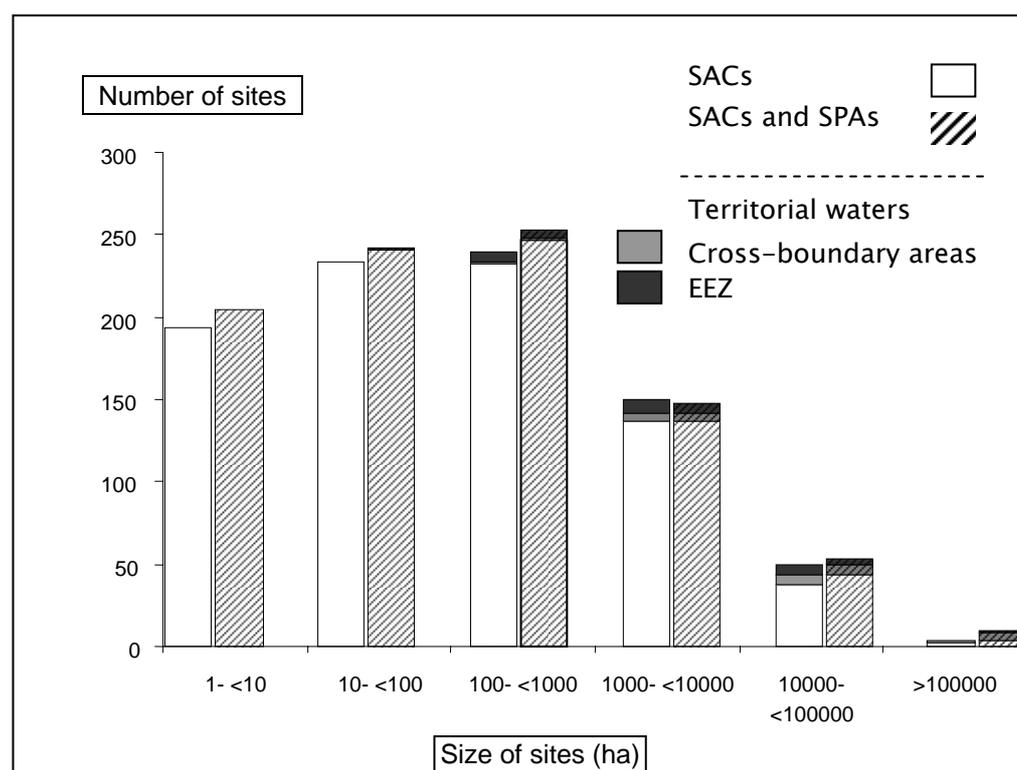


Figure 3. Size distribution of Natura 2000 sites: SACs only and SACs and SPAs combined. The sizes are shown separately for sites in territorial waters, in exclusive economic zones (EEZ) and for sites that reach over the EEZ boundary (cross-boundary areas). Note that the amount of coverage of SPA sites alone cannot be read out of the graph since there is overlap in areas between the two networks.

Representativeness: there are major gaps in both the geographical distribution of sites, as well as in the representation of benthic marine landscapes.

In total, 10 percent of the territorial waters and only 3 percent of the EEZs in the Baltic Sea are designated as SACs. Including SPAs to the network would increase the values to 16 percent and 4 percent respectively. The proportionate coverage of sites differed also considerably between the Member States. Germany is the only Member State with a designated area covering over 20 percent of its waters, and also the only country where the coverage of sites in the territorial waters and the EEZ is more or less equal.

None of the six Baltic Sea sub-regions reached the recommended minimum 20 percent SAC coverage. The low-salinity sub-regions are the least protected (the Bothnian Sea, 2% and the Bothnian Bay, 5%). In comparison, Kattegat (15%) and the Gulf of Finland (15%) had better coverage.

Only 19 out of 60 benthic marine landscape types were adequately represented, i.e. fulfilling the required 20 percent representation (Table 1). The SACs cover mainly shallow coastal areas/territorial waters and thereby most benthic marine landscape types in the non-photoc environment are inadequately represented. Least protected are the landscapes dominated by hard clay and mud. (Figure 4). The Habitats Directive, as it is formulated today, does not cover e.g. soft bottom habitats in the deeper waters and therefore does not encourage designation of sites in these areas. This means that the directive does not contribute to the protection of those marine landscapes that are most affected by one of the most serious environmental threats in the Baltic Sea, i.e. the oxygen depletion caused and/or enhanced by eutrophication (see BALANCE Interim Report no. 10 and no. 17).

The 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 percent. This is hardly surprising since it does not require a large total area to cover a large proportion of a rare landscape type while it requires a huge area to cover the same relative coverage of a widespread landscape.

Table 1. 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

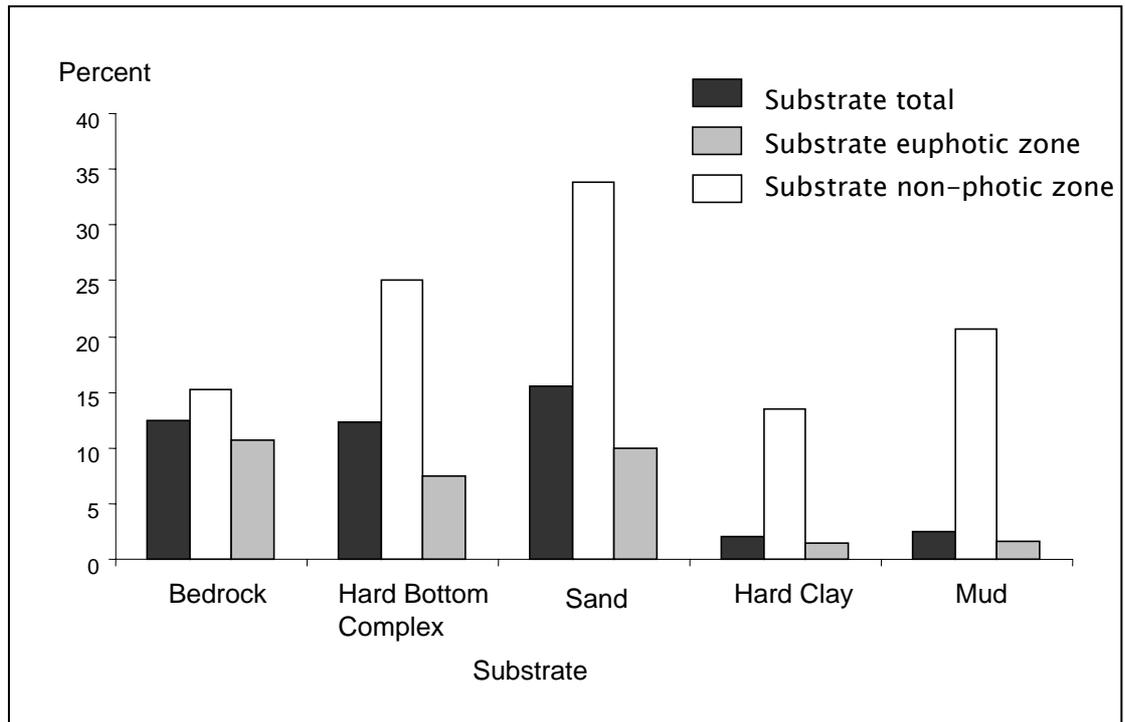


Figure 4. Proportion of bottom substrate types within SACs in the whole Baltic Sea area (black), in euphotic zone (white) and in non-photic zone (light grey).

Replication: the number of benthic marine landscape patches within the Natura 2000 network was generally quite high, with only a few exceptions, which most likely results from the natural patchiness of the Baltic Sea marine landscapes. It was concluded, however, that defining a replicate still needs further development. In addition, the landscape level approach was not ideal for assessing replication, as the minimum size for a patch to be considered a replicate and the adequate amount of replicates needs to be set species-specifically.

Connectivity: when applying a applying a fixed 25 km dispersal distance, for the five benthic marine landscape types selected for the assessment, the majority of the patches were connected to at least four other patches. Areas of relatively high level of connectivity were concentrated in coastal areas, which is a result of a lack of sites in the offshore areas. Hence, the network is not well connected for species inhabiting mainly or only deeper offshore areas.

When applying the species-specific approach we found that the network is relatively well connected for common and widespread species with dispersal distances of 25-100 km. We can not, however, be certain that all replicates included in the assessment are large enough to support viable populations of species. For short distance dispersers, however, the network is not well connected.

When assessing connectivity using a 1 km dispersal distance and landscapes suitable for *Fucus vesiculosus*, connectivity between landscape patches was found to be poor. This result is worrying, especially when keeping in mind that *Fucus vesiculosus* is a keystone species in the littoral zones of the coastal areas,

where most of the SACs are found. It is also an important species in many of the Natura 2000 habitat types, which the network aims to protect.

Both within and between site connectivity are important for a network to be considered well connected. Connectivity within a site is important for short distance dispersers that occur in fragmented habitats. Adequate connectivity between sites is important to secure dispersal and genetic exchange over large areas.

There is, in most parts of the Baltic Sea, often a substantial degree of geographical overlap between sites designated under the Habitats and the Birds Directive. Including SPAs in the assessed network only slightly improved the overall coherence of the network, with noticeable effect primarily in Danish, Estonian, German and Polish waters.

To summarize, the network is not ecologically coherent. None of the four criteria were fulfilled.

Recommended actions: throughout the project we have identified a number of actions which would improve the ecological coherence of the Baltic Sea SAC network:

1. Designation of more sites in the deeper offshore areas, especially where the landscapes are dominated by mud and hard clay. This would also improve connectivity between sites. In this process it is important to identify those sites that are not influenced permanently or regularly by severe oxygen depletion.
2. Designation of more sites in the areas of low salinity (Bothnian Sea and Bothnian Bay).
3. Designation of larger sites. This would reduce the bias towards sites that are too small and is also most likely to enhance connectivity within sites for the short distance dispersers.

This assessment was a first attempt to assess the ecological coherence of the Baltic Sea Natura 2000 network, using GIS and statistical analysis of geographical data. The assessment shows that it is possible with currently available methods, but the lack of existing clearly formulated conservation goals, and sometimes the lack of ecological knowledge make the assessment of all four elements of coherence uncertain.

The assessment of representation of benthic marine landscapes was developed farther than the assessment of replication, connectivity and adequacy since more work has previously been done on representativeness in the international literature, but also because the latter three require more detailed information on the ecology of individual sites and features, and more specific goal formulations.

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 of biological commu-

nities can be used as a first approach, but in order to improve the assessment, more data on distribution of species and habitats as well as better ecological knowledge on the requirements of the species are 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. The assessment assumed a similar dispersal of species to all directions, which is not altogether realistic.

The analyses still generated valuable information. As long as the gaps in the network are more or less obvious, the methods do not need to be more precise. The methods should be developed further in parallel to the improvement of the network itself.

The following two chapters describe frameworks and methods which can be used to improve coherence of the existing network. Chapter 3 proposes a step-wise decision-making process for improvements in network connectivity and Chapter 4 presents a method for improving network representativeness.

Box 1. Case Study BALANCE Pilot Area 3

Swedish archipelago - Åland - Finnish Archipelago Sea

A pilot area case study was also carried out with the aim to assess ecological coherence of the network from the perspective of the habitats that the Natura 2000 network is actually aiming to protect, i.e. the habitats listed in Annex I of the Habitats Directive. The assessment included six Natura 2000 habitats, using distribution models produced within the project (BALANCE Interim Report no 30): *estuaries* (1130), *coastal lagoons* (1150), *large shallow inlets and bays* (1160), *reefs* (1170), *esker islands* (1610) and *boreal baltic islets and small islands* (1620).

Modelled distribution maps of five essential fish habitats (BALANCE Interim Report no 11) were also used for a similar assessment with regard to the network's protection of: perch spawning habitats and perch, pike, pike-perch and roach nursery habitats. The Habitats Directive does not aim to protect fish. Sites protected by the Habitats Directive are still likely to maintain a higher habitat quality for many fish species, in comparison to unprotected habitats.

The approach used to assess the network in the pilot area was similar to the approach used in the Baltic Sea scale assessment. In some cases, however, setting more detailed criteria was also possible e.g. according to the requirements of the Habitats Directive and definitions of the Annex I habitats. The method is fully described in BALANCE Interim Report no 25.

The SACs in the pilot area are generally small; only a minor fraction of the areas are over 1000 ha in size. Although the SPAs are generally larger than the SACs, adding them to the network did not change the result much. Since many sites are relatively small, they often only protect parts of some of the larger habitat types, e.g. *estuaries* or *large shallow inlets and bays*. In some cases habitat patches are even protected in fragments by several sites.

The SAC network protects 7 percent of the total coverage of all the six Natura 2000 habitats assessed. None of the six habitats were adequately represented, i.e. fulfilling the minimum requirement of 20 percent representation (or 60 percent in the case of *coastal lagoons*). *Estuaries* and *reefs* were the least protected. Protection of *estuaries*

increased from 3 to 11 percent when SPAs were included in the network being assessed. (Table 2)

<i>Table 2. Representation of Natura 2000 habitats within SACs and SACs-SPAs combined.</i>		
Natura 2000 habitat	Representation	Representation
	SAC (%)	SAC+SPA (%)
Estuaries (1130)	3	11
Coastal lagoons (1150)	15	16
Large shallow inlets and bays (1160)	8	9
Reefs (1170)	5	7
Esker islands (1610)	16	16
Boreal Baltic islets and small islands (1620)	7	10
Total	7	10

The five essential fish habitats were as poorly protected as the Natura 2000 habitats. As little as 3-6 percent of the habitats were covered by SACs. Poor representation of these fish habitats can be related to poor representation of many Natura 2000 habitats, as shallow vegetated habitats (e.g. *estuaries*, *large shallow inlets and bays*, *coastal lagoons* etc.) are often also important habitats for fish.

Most of the Natura 2000 habitats had a relatively high number of replicates within the SAC network, especially habitat types that are widely spread in the pilot area and found in small and numerous patches. The identified replicates, however, may not always be large enough to support viable species communities. Since many of the protected sites are relatively small compared to many habitats, they often protect only fragments of some habitats, fragments which might be too small to be considered a replicate. For example, *estuaries* had only eight replicates within the network and all of them, except for one, were only parts of *estuaries*, not fully protected habitat patches.

The replicates were often also unevenly distributed across the pilot area which is one of the factors affecting connectivity. For some habitats, large gaps in connectivity between protected patches were identified, even when there was good potential for connectivity (i.e. in assessments done using 25 km dispersal distances). Gaps in long-distance connectivity were shown for *Large shallow inlets and bays* in the Finnish part of the pilot area (including Åland, see Figure 5), for *Esker islands* around Åland and the Swedish part of the area and also for *coastal lagoons* in parts of the Finnish Archipelago Sea and in some areas around Åland.

The connectivity assessments carried out using short dispersal distances (1 km) again showed large gaps in the network. Most of the habitat patches did not even have potential to support connectivity between sites for short-distance dispersers. Protected patches of those habitats that did have potential (e.g. *reefs*, *coastal lagoons* or *boreal baltic islets and small islands*) were still too far from each other. The only exceptions were the parts of the pilot area where the largest SACs are located. These larger sites were also able to support connectivity within sites for short-distance dispersers.

These larger SACs were also important for the connectivity between perch spawning areas (10 km dispersal distance) and pike nursery areas (5 km dispersal distance) within the sites. This suggests that unless the small sites are relatively close to each other, large protected sites are probably more effective in supporting connectivity than small ones, even for species that have potential to disperse or migrate 5-10 km. Generally, the connectivity between protected fish recruitment habitats was found inadequate.

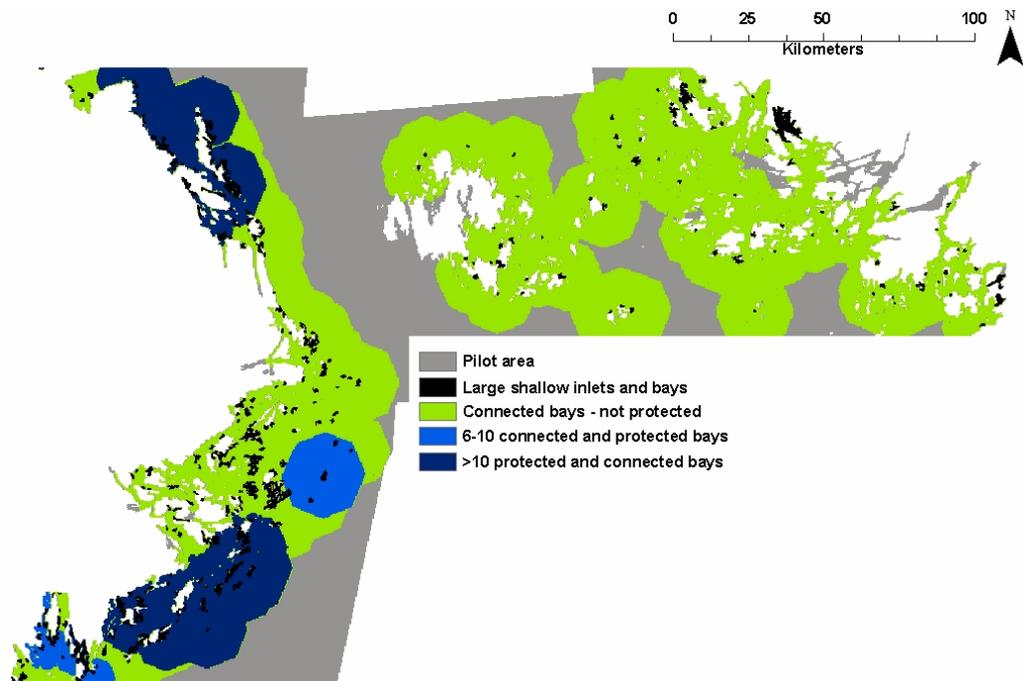


Figure 5. Connectivity of large shallow inlets and bays, using 25 km dispersal distance. Green areas represent areas within the dispersal range from all large shallow inlets and bays (potential for connectivity) and blue areas represent areas within 25 km dispersal distance of protected bays.

3 PLANNING FOR CONNECTIVITY THROUGH BLUE CORRIDORS

Marine areas do not exist in a vacuum, they are all linked to other areas on land or in the sea. This linkage is important both for the movement of organisms, but also for the connection and exchange of ecological processes. It is therefore important not only to consider the extent, values, and management of individual areas, but also to start thinking about the role of a single area in a network of areas. By starting to make such network planning, the possibility that individual areas actually fulfil their goals will increase, but what do we know about the connectivity in the Baltic Sea, what is the importance of connectivity, what causes and hinders connectivity and how do we define and plan for blue corridors? These are some of the questions we have tried to answer in this chapter.

Much of the conservation work has, until now, been directed towards individual species. In the BALANCE project, we emphasize the protection of habitats as an important way forward in marine nature conservation: by preserving the habitats we may also preserve the species living in them.

Some species migrate over long distances, meaning that their habitat is either not in a fixed location or is only so during a certain part of their life cycle. Many species are also dependent on several different habitat types during their life. In such cases, the population dynamics in one place may be driven by factors in another place.

In any area there will be a turnover of species. Populations are seldom in a steady state: some species will from time to time go locally extinct, either as a result of predictable long-term processes or as a result of random events. The risk that local extinction occurs depends on the size of the habitat. The bigger the habitat and the larger the population, the smaller the risk that local population dynamics lead to extinction within the habitat. After a species has disappeared from an area, it may recolonize the area again after some time. The species assemblage in one place therefore depends on both the characteristics of the habitat and how populations within the habitat are interconnected with other similar habitats in other areas. Thus, in order to ensure the long-term survival of a species, the connectivity of habitats may be as important as the quality and quantity of the individual habitat.

The exchange of individuals between sites may be difficult to quantify, whether or not the organisms are subject to passive dispersal or self motile. The exchange between sites, however, is not only a matter of the physical distances: some environments may be more or less hostile to cross, such as water for terrestrial species or land for aquatic species. Barriers may be natural or created by humans. Spatially separated habitats can also be interconnected by “corridors” which facilitate an efficient population exchange between two sites. Corridors can be routes that intersect barriers like valleys, rivers, etc. They can be attractive routes for migrating organisms to follow because of food, water, shelter etc. In the marine environment corridors may be very concrete physical fea-

tures, such as coastlines, sandbanks or deep channels. These “blue corridors” can also be defined by optimal water temperature, salinity or oxygen condition. In case of passive dispersal, corridors may be defined by prevailing winds or in the marine environments, by currents. Corridors can also emerge from human activities such as shipping (ballast water). In this latter case, it may have negative effects as it serves as a stepping stone for invasive species.

What is a blue corridor? Definition used in the BALANCE project:

A blue corridor is a route of particular importance in the sea for the population exchange between locations and of importance for the maintenance of biogeographical patterns of species and communities. Blue corridors are shaped by interplay between the biological characteristics of a species, the physical/chemical characteristics of an area, and the geographical location of habitats. Blue corridors can therefore either be concrete physical features or the preferred or realised route of spread of a species

3.1 What do we know about connectivity in the Baltic Sea?

An organism’s response to habitat fragmentation is dependent on its life history and distribution traits and may vary on different temporal and spatial scales. Rare species are likely to be more sensitive to the adverse effects of modification of habitat. Protection of a specific habitat may be ineffective if related habitats are left unprotected. Conservation strategies need to incorporate the protection of areas with heterogeneous habitats that are important to meet the changing habitat requirements of complex life cycles. Corridors between habitat fragments or patches reduce the rate of species loss and enhance the recolonization of habitat patches. To date no descriptive or manipulative studies exist that combine the effect of spatial orientation and fragmentation of habitats in the Baltic Sea area. Thus, it becomes necessary to evaluate the effect of spatial distribution of habitats at various spatial scales on benthic macroalgal, invertebrate and fish communities.

Many Baltic Sea species show large spatial dispersal during a larval phase and, in case of migratory or pelagic species, during an adult phase. How this connects different areas to each other still remains largely unknown, because many larvae can be confined to certain nursery areas close to the spawning area by active use of local water circulation patterns rather than passive drift by the currents. Also, the semi-planktonic strategy, suggests that planktonic larvae may retain near shoreline or littoral bottom and thus, population mixing is probably not a rule and the connectivity of areas weak. Larval strategies, however, are not straightforward and different abiotic and biotic factors may force larvae to switch to another strategy.

This said, in the literature review on blue corridors in BALANCE Interim Report no 4 (and also e.g. in BALANCE Interim Report no 25) we show that some data relevant to the analysis of connectivity is available. In addition, tools are available to use this information to produce results that are highly relevant and useful when designing networks of marine protected areas, as shown in the

case study below. More data, however, and ecological knowledge and information are still needed.

Box 2: Case studies on hydrographic models of larval transport

A case study was carried out to demonstrate the importance and capacity of passive transport pathways of pelagic life stages of marine flora and fauna in the Baltic Sea (BALANCE Interim Report no 9). Results from two different tracer studies show the dispersal by currents and turbulent mixing of water masses for different parts of the Baltic Sea area. These studies simulate potential “blue corridors” between several locations in the Baltic Sea.

The first study included a “conservative tracer”. A conservative tracer has no decay (mortality) and therefore its distribution is controlled solely by currents and mixing. Such studies are suited for documenting long-term transport covering a period of more than one generation of planktonic life stage. Figure 6 shows some examples of transport of conservative tracers in the Baltic Sea.

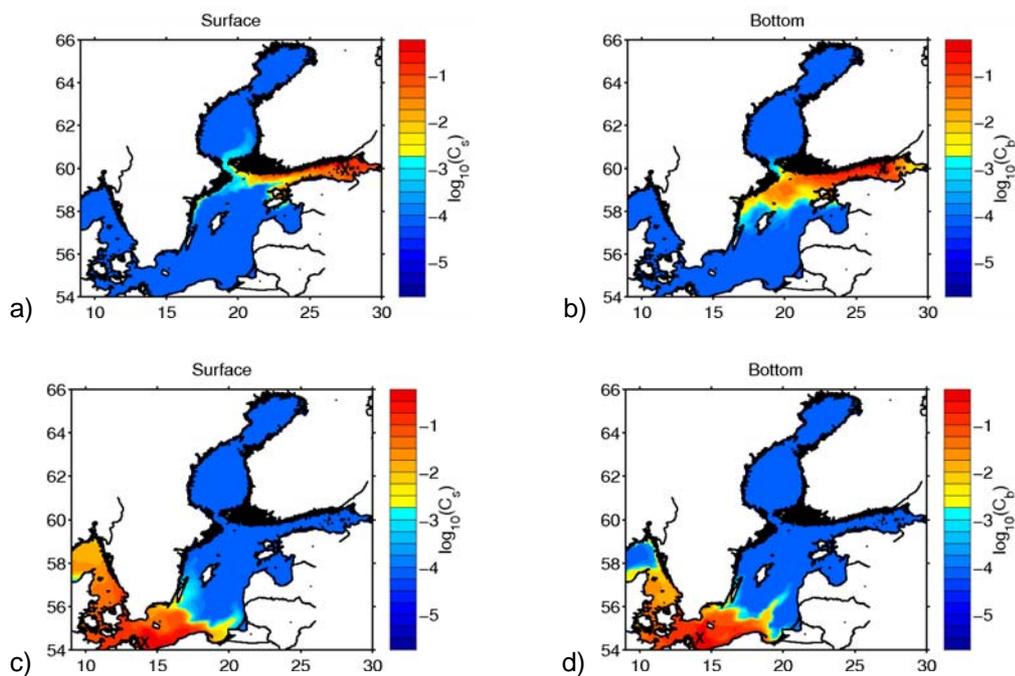


Figure 6. Model results of the mean concentration in July of conservative tracers that continuously have been released throughout the water column during a 6-month period at 5 locations. The source is marked with X, where the concentration is always one. a and b) The concentration at the surface and bottom for a tracer released at Itäisen Soumenladen saaristo ja vedet (position 27° 0'E 60° 20') c and d) The concentration at the surface and bottom for a tracer released at Adler Grund (position 14° 10'E 54° 40'N)

The second study included a “non conservative tracer” having a decay rate that represents the behaviour of a larva, a propagule or other kind of biomass that are also controlled by biological processes, e.g. mortality. Figure 7 shows two examples of non-conservative tracers spreading from Natura 2000 areas with reef habitats in Kattegat.

The attempt to quantify the role of blue corridors concerning passive dispersal using the tracer approach confirms that dispersal in fact can 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 a 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 could potentially be lost as they may spread over unsuitable areas.

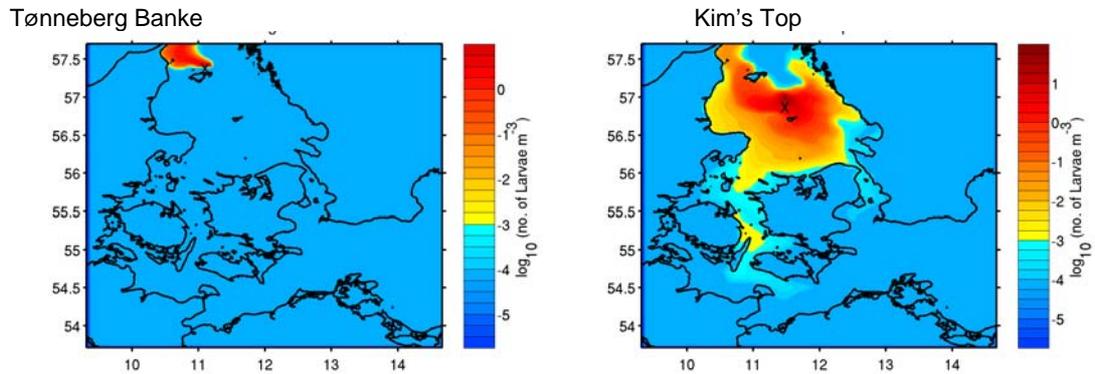


Figure 7. Model results that show the mean concentration in July of non-conservative tracers in the model bottom layer. The tracer had continuously been released from 9 locations throughout the water column, the site of which is marked with an X, during a 6-month period. Left Tønneberg Banke: 11° 16,26'E 57° 28,328'N, Right: Kim's Top: 11° 35,42'E 57° 00,78'N

Furthermore, this tracer study also shows that the relative role of a certain area as a source of pelagic larvae or propagules does indeed vary and that the concept of ranking areas in “downstream” and “upstream” locations is possible and makes sense (Figure 8). 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 was clearly a “downstream” area (Herthas Flak & 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 helping to maintain population and biodiversity in adjacent areas.

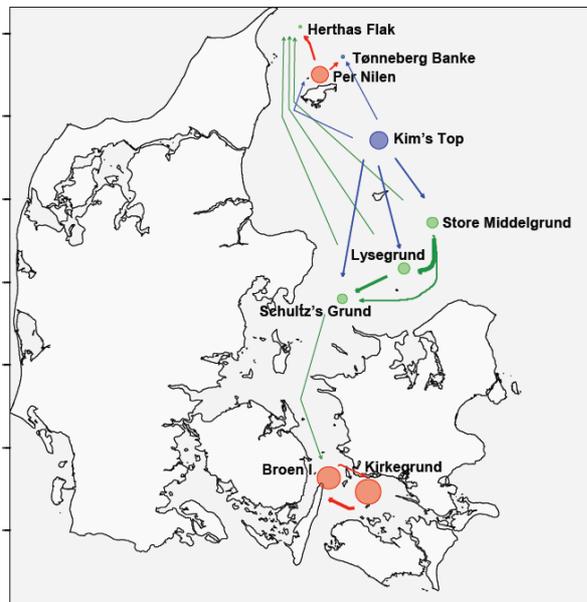


Figure 8. Overall dispersal routes of tracers in the Kattegat and Belt Sea. Diameters of circles are scaled proportionally to average tracer concentration in the bottom layer.

In 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 as stepping stones of certain stone reef could be evaluated using the same tracer approach.

The present examples have assumed 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 need many different dispersal strategies to be tested and that the modelled period extended to a whole year. Running the model for several years characterized by different weather conditions would also be a major step forward.

3.2 Planning for a well connected MPA network

If the assessment and planning for improved connectivity is done in a stepwise process with a defined sequence of actions and decisions, it may be easier both to analyse the individual area and to compare the conservation effect of including different areas (an important task if a network of areas is analyzed). The aim of this part of the BALANCE project was therefore to develop a stepwise process to guide the improvement of connectivity of MPAs. Here is a proposal for such a stepwise decision-making process with nine decision steps organised in 3 major blocks (Figure 9).

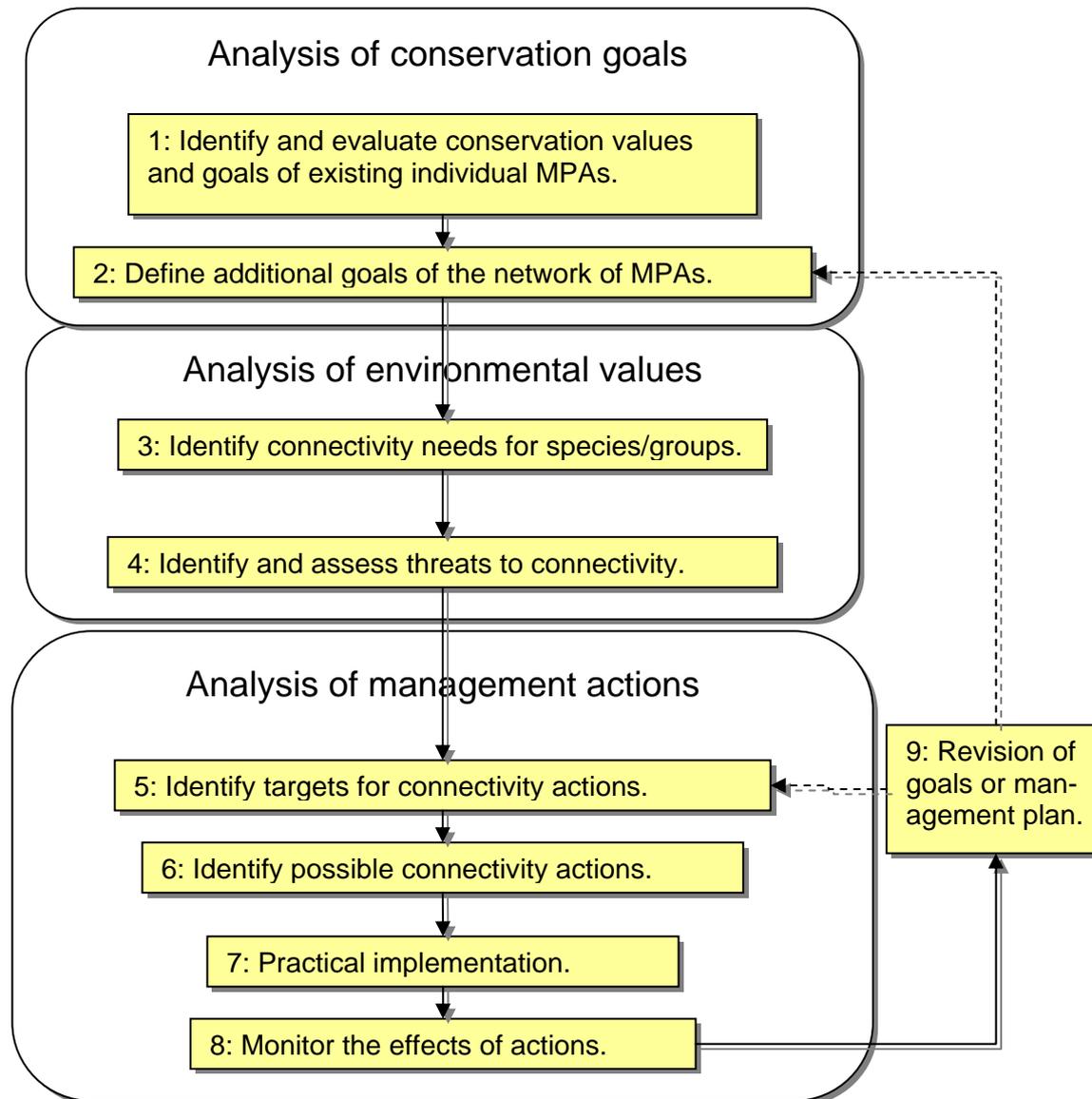


Figure 9: Outline for a possible scheme for a systematic analysis of connectivity between marine areas.

Block I: Defining and identifying conservation goals

1. Check the goals and targets of existing MPAs.

The first action towards improving the connectivity is to gather information concerning the goals of existing MPAs. There are many different schemes for setting goals for an MPA. Commonly, overarching goals are combined with

more precise objectives and criteria for evaluation. Many feel that it is difficult to formulate such precise statements, but there is much to gain if this could be done for each MPA. Interested readers could consult documents such as the IUCN report “How is your MPA doing” (Pomeroy and others 2004).

2. Define possible additional goals to be achieved by a network.

The second action is to determine if additional goals can be achieved with an ecologically connected network of MPAs. These could be goals related to values already defined in individual MPAs, but with a greater chance of being met by the entire MPA network. It could also include values not explicitly mentioned in any individual MPA, but mentioned in other policies (locally, nationally or internationally) e.g. protection of widely spread species. Whether or not such additional goals could be achieved, partly depend on whether or not blue corridors play a significant role for population exchange between the area of interest and other areas.

Block II: Defining and identifying environmental values and threats

3. Identify the connectivity needs for invertebrates, plants and algae, fish and mammals.

Although detailed information on connectivity needs of species and populations is often missing, there is basic information available on the reproductive biology (larval vs direct development) and migration ecology of many species. This information can at least be used to make initial analyses if connections to other areas are likely to be important to the population processes of the area of interest.

4. Identify and assess potential threats and limits of connectivity, e.g. describe water movement, assess destruction of habitats and increased fragmentation, assess changes in habitat quality (pollution, eutrophication), and assess over-harvesting of commercial species.

This step is essential in order to formulate concrete actions. Natural and human processes may contribute to limiting the dispersal. Preferably, the consequences for the connectivity in MPA networks of any constructions should be assessed. Human disturbances may be physical (e.g. construction, exploitation) or chemical (pollution). Information on the extent of human activities is probably easier to find than information on the biological characteristics of dispersal.

Block III: Defining and identifying management actions

5. Identify targets for management actions concerning connectivity.

Identifying quantitative targets (e.g. predicted dispersal ranges) may be the most difficult part in the process to improve and ensure connectivity. In many cases, agencies prefer to formulate outcome-oriented targets rather than action-oriented targets but if outcome-oriented targets can not be formulated because the necessary level of information is missing, action-oriented targets may be better than not formulating any targets at all.

6. Identify the possible actions.

In most ways, the knowledge, methods and regulations used to identify actions to ensure connectivity are no different than what is already used in marine envi-

ronmental planning. The difference is the additional emphasis not only on effects on the area where the threat occurs, but also on effects in other areas.

7. Practical implementation (stakeholder involvement, cost assessment, prioritising).

The process will probably not differ in any fundamental way if the planning is for an MPA with connectivity or for an “independent” MPA. Some parts of the implementation, however, e.g. stakeholder involvement and support, may be more difficult. One way to facilitate the process may be through careful formulation of goals and targets both for individual sites and for the network of sites.

8. Monitor of the effects of the actions.

Monitoring the outcome of actions is important, but depends on how the goals and targets are formulated, and on the resources available for monitoring. In practice, goals and targets should be influenced by the possibility to monitor them.

9. Revise the management plan.

There is a cost (e.g. financial, time, credibility) to change an existing management plan, but it is a waste of resources to have a management plan that does not meet the goals. The rules of how, when, and by whom the plan may be revised should be formulated in the management plan.

3.3 Discussion

Marine areas, including MPAs, are all linked to other areas on land or in the sea. This linkage is important both for the movement of organisms, but also for the connection and exchange of ecological processes. It is therefore important not only to consider the extent, values, and management of individual areas, but to start thinking about the role of a single area in a network of areas. There are plenty of international examples of involvement of connectivity matters in MPA planning but this approach has so far been very weakly implemented in the Baltic Sea area.

A blue corridor is a route of particular importance in the sea for the population exchange between locations and of importance for maintaining biogeographical patterns of species and communities. Blue corridors can either be concrete physical features or the preferred or realised route of spread of a species.

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 tracer study also shows the variability and importance of passive transport pathways of pelagic life stages of marine flora and fauna. This kind of knowledge is very important when connectivity between existing Marine Protected Areas (MPA's) is evaluated. Knowledge of blue corridors is also important if, or rather when, important management tools such as zoning of marine areas are applied. Protection of important stepping stone areas and habitats acting as donor areas or nursing areas during a lifecycle is an obvi-

ous way to protect or restore biodiversity in a highly effected and exploited area like the Baltic Sea.

Our knowledge of actual connectivity patterns and the importance of blue corridors in the Baltic Sea is still limited. However, as shown by the literature review (BALANCE Interim Report no 4) and the practical manual on blue corridors (BALANCE Interim Report no 18), complete knowledge of the ecology of species and habitats is not necessary for the practical management of connectivity: current knowledge, combined with a systematic use of existing methods, may significantly help to improve the planning for connectivity e.g. among MPAs.

4 SELECTING A REPRESENTATIVE MPA NETWORK

A representative network of marine protected areas (MPAs) should ensure that all marine landscapes, habitats, species and ecological functions in a region are adequately protected. The aim of a representative network is to protect the entire ecosystem and not just specific species or habitats. The sites in a representative network should also be adequately distributed across the different biogeographic regions to ensure inclusion of possible genetic variation of species on community level and variation in ecosystems.

Protection of a representative and accurate share of each landscape type or habitat will most probably also cover unknown biodiversity. A network of representative sites can therefore be seen as an insurance strategy when the exact distribution of many species is unknown.

The coherence assessment presented in chapter 2 revealed severe gaps in the representativeness of the existing Baltic Sea MPA-network. The aim of our work has been to develop and test a regional, systematic approach that can be used to select a representative network of sites in the Baltic Sea, spanning across national boundaries. This chapter briefly summarizes the results presented in BALANCE Interim Report no 24.

4.1 A systematic approach to selecting a representative network

The need for a systematic approach for planning in the marine environment is by now widely recognized and provides a transparent, scientifically credible and efficient framework for establishing MPA networks. Such an approach also increases the likelihood that the network meets the defined conservation criteria and management objectives, while making efficient use of the available resources.

Despite this, such an approach has so far been lacking in the Baltic Sea. The site designation process has been very slow and often done on an ad-hoc, site by site basis without regional coordination. Expert knowledge and opinion has often biased site designation towards areas with unique habitats and specific focal species and scenic areas with high recreational value. Many of the sites designated in the Baltic Sea have a terrestrial component such as important bird areas or seal skerries. These sites have rarely been selected based primarily on marine biodiversity values below the sea surface.

A systematic and regionally coordinated approach is especially important in the Baltic Sea region where nine countries share the responsibility of protecting and managing the Baltic biodiversity. In this project we have developed and tested an approach to select a network of MPAs which aims to represent the full range of biodiversity and ecosystem functions in the Baltic Sea and at the same time attempts to minimise the cost and impact on other interests. We have focused our efforts on selecting a network of sites representing the full range of benthic marine landscapes. One of the main principles has been to build on ex-

isting MPAs by selecting new sites that complement already designated sites under the EC Habitats Directive.

The computer based decision support tool MARXAN (see Box 3) was used to support/help the selection of a representative network in the Baltic Sea. Decision support tools are helpful in a systematic site selection process where consideration of large amounts of spatial data and an enormous number of possible combinations of sites is required, a task that is virtually impossible without computer support. Having been used successfully in other parts of the world, the BALANCE project introduced and tested MARXAN into the Baltic Sea context.

4.1.1 Methodology – principles and criteria

When establishing a network of marine protected areas, it is crucial to define which species, habitats and ecological processes could adequately represent the marine biodiversity in the region and for which the network of marine protected areas should be designed, and how much is needed to ensure long term viable populations.

Ideally, an assessment should include data to ensure that all biodiversity is represented. Mapping of every population, species and habitat type as well as the interactions associated with them, however, is impossible. Therefore, the use of “coarse filter” conservation features that act as surrogates for the broader biodiversity is a main component in this assessment. The “coarse filter” is expected to capture the full range of biodiversity in the study area by representing broad scale ecological units, such as benthic marine landscapes. More specific species, habitats and features that are important to include in the network, but that may slip through or not be represented by the “coarse filter” e.g. threatened, rare or declining species or habitats, were also included as a “fine filter”.

The original list of suggested conservation features (see BALANCE Interim Report no 24) was revised on the basis of spatial data availability and access. Only species and habitats for which there was access to reliable and coherent spatial information covering the entire Baltic Sea were included in the analysis. Since this site selection exercise should be considered an iterative and constantly improving process, the other conservation features could be included later when more and better information becomes available.

Within the BALANCE project, the aim has been to set conservation targets in line with scientific recommendations, but the probability of further implementation of the recommendations of the project increases if the targets also are in line with political agreements. We have, therefore, tried to incorporate both these aspects into the conservation targets.

It can be discussed whether uniform targets should be used for benthic marine landscape representation or if specific targets should be set based on some measure of distribution and abundance or threat to the individual features, such as lower targets for more common soft bottom landscapes in the non-photic zones and higher conservation targets for more rare or threatened landscapes. Moreover, it may be relevant to set different targets for features of different

quality, such as, for example, deeper muddy areas with high and low oxygen content. When discussing targets it should be kept in mind that the area around many protected sites will still partly support some species and ecosystems.

The conservation features to be represented in the network are listed below. Uniform targets were set for the coarse filter features, whereas individual targets were set for the fine filter features.

Conservation features and targets

The benthic marine landscapes, mapped within the BALANCE project, were the primary coarse filter conservation feature for which the portfolios (i.e. the set of selected sites) have been selected. The modelling of benthic marine landscapes was based on variation in bottom substrate, photic depth and salinity and should be seen as surrogates for the broad scale variation in biodiversity in the region. Altogether, 60 benthic marine landscapes were identified in the Baltic Sea (See Figure 1, Chapter 2). (For more details on benthic marine landscape see BALANCE Interim Report no. 10).

It was decided to explore three uniform representation target scenarios according to three levels of conservation ambition. In each of the target scenarios, all benthic marine landscapes were assigned the same (uniform) target. The selected sites should represent a minimum quantity of all benthic marine landscapes. The following target scenarios were analyzed:

I.	Recommended minimum level of protection	20 percent
II.	Lower ambition than recommended minimum level	10 percent
III.	Higher ambition than the recommended minimum level	30 percent

In addition to the coarse filter features, the following fine filter conservation features were included:

Cold water corals (Lophelia pertusa, Paramuricea placomus, Primnoa resedaeformis). Cold water corals are very rare with few occurrences in the region (only in Skagerrak). They are also highly threatened due to trawling, which was the motive for setting a very high representation target of 100 percent for living corals. A lower target of 60 percent was set for dead structures.

Areas of importance for sea birds (Important Bird Areas, IBAs). The IBAs were given uniform targets following the same target scenarios as the coarse filter features (20%, 10% and 30%).

Haul out sites for grey seal (Halichoerus grypus). In accordance with the guiding principles of the Habitats Directive, a representation target for the grey seal haul out sites was set to 60 percent in all scenarios.

Network Principles

In addition to setting representation targets, criteria for spatial representation in the region were also set, e.g. to guarantee that the network of sites fulfils some basic principles. The principles are summarized below:

1. All existing protected areas should be included in the selected network. Complementary sites should be added to the designated Natura 2000 sites.

The Habitats Directive network is currently the best available framework for implementation of a broad scale representative network for protection of the benthic environment in the Baltic Sea. It was therefore decided to build on the existing sites by ‘locking in’ designated Special Areas of Conservation (SACs) into the portfolio and then selecting additional complementary sites to fulfil conservation targets.

2. Each conservation feature should be represented to their target within each ecologically different sub-region and political unit (exclusive economic zone).

Stratification of targets also ensures a certain amount of replication i.e. that all features are represented more than once to spread risk from stochastic events. Moreover, stratification can ensure protection of unknown biodiversity, possible genetic variation of species on the community level and variation in ecosystems as well as distribute the sites to spread risk. Stratification was also used to guide the distribution of sites spatially, i.e. between political units, such as national boundaries.

3. Socio-economic factors and the suitability of sites should be taken into account.

The representation targets should be met with a minimum impact on other interests and the relative suitability of potential conservation sites should be considered. A “suitability map” was therefore created and used in the analysis to guide the selection of sites away from areas less suitable for conservation, due to conflicting interests, and towards areas offering equal conservation values in a more suitable environment. Unsuitable areas are, for example, areas with a high level of threat or high conflicting interest. Oil terminals, harbours, shipping lanes, population density and areas of high risk for oil related accidents were incorporated into the suitability map representing areas to be avoided. Unfortunately data on several activities, such as fisheries, were not available.

4. The size of the selected sites should reflect the broad scale objective of the exercise.

Relatively large sites should be selected for protection on a regional scale. The selection aims to be as efficient as possible in terms of the area selected. However, a set of sites being maximized in terms of area efficiency usually results in a highly fragmented network, which is less likely to be implemented, and also likely to be undesirable from an ecological point of view. There is therefore a trade-off between area efficiency and cohesion. The spatial scale of the ecological processes and the broad scale ecological objective of this exercise has been the guiding principle for determining the most suitable amount of clustering of the sites within the portfolio. The selected portfolios therefore all have relatively large patches of selected units.

Site Selection

MARXAN (version 1.8.6; see box 3) was used to demonstrate the selection of a representative network of marine protected areas (or portfolio). Several scenarios were explored, with different targets and where the existing MPAs (Natura 2000 sites) were, or were not, included in the network design. The scenario with a minimum 20 percent representation target and with the existing SACs included is likely the most informative for envisioning a network of Baltic Sea MPAs.

Box 3. MARXAN; a tool for site selection

MARXAN (Ball & Possingham, 2000; Possingham et al, 2000) is a tool that provides decision support to teams of conservation planners and local experts identifying efficient and comprehensive networks or 'portfolios' of suitable planning areas that combine to satisfy a number of ecological, social and economic goals. It is readily available via the Internet at no cost (<http://www.ecology.uq.edu.au>). It is a stand-alone program that requires no other software to run, although a GIS is required to prepare the data, make the input files and to view the results.

MARXAN offers decision support for teams choosing between hundreds of biodiversity conservation features and thousands of candidate areas or 'planning units'. Using a transparent process that is driven by quantitative goals, the analysis is repeatable and objective. It is designed to help automate the planning process so that a team of planners can offer many different conservation plan scenarios in a forum for consultation with stakeholders.

Planning criteria to improve various aspects of the portfolio can be included in the analysis. These include measures to improve connectivity, ensure the existence of repeated examples of conservation features and to make sure a portfolio is built that includes sites that are placed far enough apart to form part of a risk spreading mechanism for local disasters. A measure of site suitability can also be included. This can help guide the selection of site towards or away from certain areas.

MARXAN is a tool that has been utilized by planning teams across the world. These include the Australian Great Barrier Reef Marine Park Authority, who designed a new zoning and protected area plan for the Great Barrier Reef using MARXAN.

4.1.2 Results and Discussion

These results aim to set out a starting point for a systematic selection of MPA candidate sites in the Baltic Sea and further insight to the extent of such a network. The results and method need to be further developed, through discussions with experts and stakeholders and through improved network design criteria and data availability. The scenarios presented are developed with the aim to demonstrate a systematic approach to selecting sites which represent the broad scale variation in the Baltic Sea.

Development of the network can be supported by two outputs from MARXAN called 'best portfolio' and 'summed solution'. The best portfolio is the one set of sites selected during repeated runs of the algorithm that meets the conservation targets and objectives in the most efficient manner. The summed solution is the number of times each planning unit was selected in the set of repeated in-

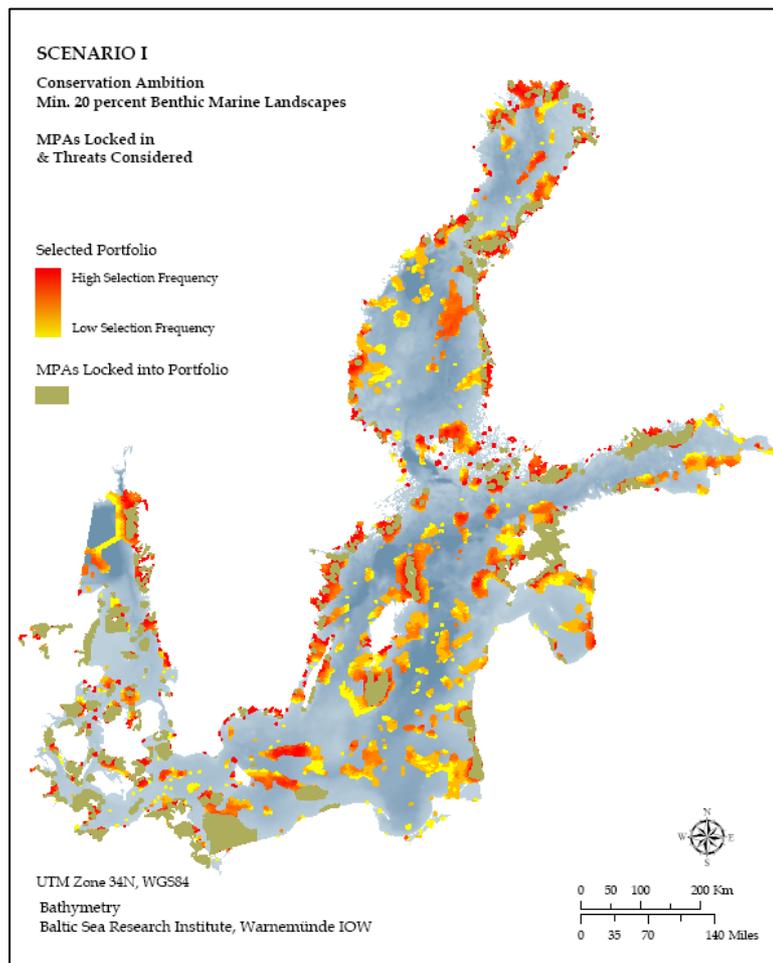


Figure 9. MARXAN "best portfolio" with the selection frequency of each unit during 100 runs. The portfolio represents a minimum of 20 percent of all benthic marine landscapes and IBAs, 60 percent of all Grey Seal haul out sites, 100 percent of all Cold Water Coral occurrences (60% of the dead structures). The portfolio adds complementary sites to Natura 2000 SACs, using $BLM=2.5$, stratified targets and a measure of suitability. The selection was done using simulated annealing with iterative improvement using 2 million iterations in 100 runs and CFPF-value 1.1 for all features.

The analysis shows that the existing Natura 2000 network coverage does not sufficiently protect the minimum of 20 percent of each benthic marine landscape. By selecting additional sites to the existing SACs, we could conclude that the area of the sites needed to fulfil the 20 percent representation target corresponded to three times the area of the existing protected sites. The total coverage of selected *and* existing sites was equivalent to approximately 30 percent of the entire Baltic Sea water surface. It should, however, be *strongly emphasised* that this number only relates to the specific analysis criteria applied in this assessment. Planning units with a high selection frequency are mainly in areas close to locked in protected areas (SACs) or in highly heterogeneous areas. Unsuitable planning units, e.g. those with an "irremovable" threat or areas with many conflicting interests such as shipping lanes and harbours are avoided and have a low selection frequency. (Figure 10).

dependent runs of the algorithm and is a measure of the flexibility of including each planning unit when building an efficient network. The best portfolio and the summed solution for the scenario representing at least 20 percent of all benthic marine landscapes are presented in Figure 9 and 10. See BALANCE Interim report no 24 for results of the other scenarios.

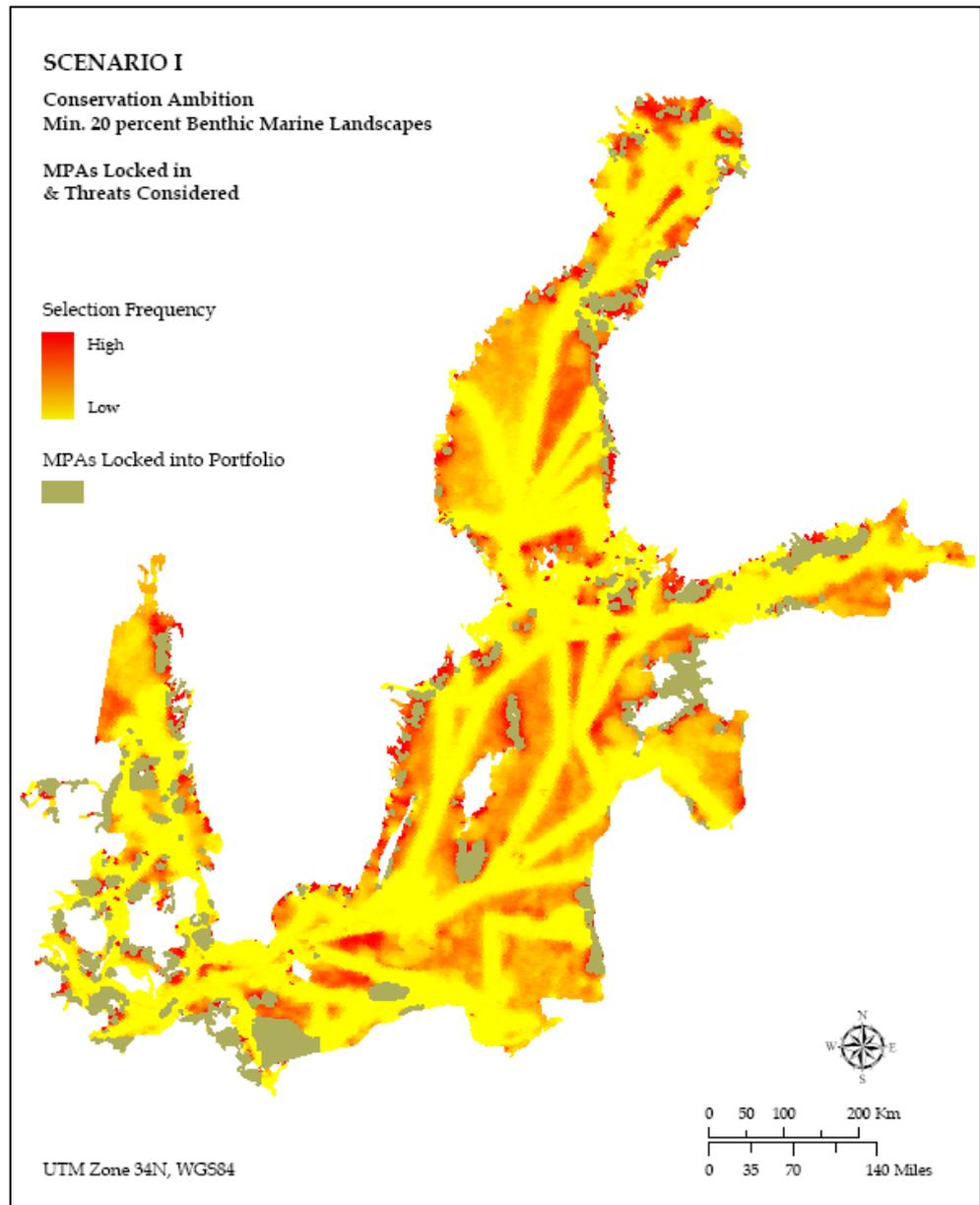


Figure 10. MARXAN “summed solution” representing a minimum of 20 percent of all benthic marine landscapes and IBAs, 60 percent of all Grey Seal haul out sites, 100 percent of all Cold Water Coral occurrences (60% of the dead structures). The portfolio adds complementary sites to Natura 2000 SACs, using BLM=2.5, stratified targets and a measure of suitability. The selection was done using simulated annealing with iterative improvement using 2 million iterations in 100 runs and CFPF-value 1.1 for all features. All targets were met.

In general, it appears as though there is quite high flexibility in reaching targets, which is mainly due to the fact that there are few overlapping conservation features. Thereby, this analysis does not fully use one of the strengths of MARXAN, to identify areas where several conservation targets can be reached in the same place, i.e. its ability to take several overlapping conservation features into account and fulfil all targets efficiently. With better data availability this could be improved.

Table 3 summarises the results of the 20, 10 and 30 percent assessments. These figures illustrate the requirement of larger portfolios as the minimum representation targets are increased from 10 to 30 percent. Also included are the alterna-

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tive portfolios, for a minimum 20 percent representation target scenario, where no existing protected areas are fixed in the initial portfolio and where both SACs and SPAs are included. These scenarios give an indication of how well the existing protected areas help meet the biodiversity conservation targets specified. The selected sites represent a *minimum* quantity of the features.

It is important to note that since a coarse filter conservation feature covering the entire study area (the benthic marine landscape types) is included in the analysis, there are no areas without conservation value. This, in combination with the low level of overlapping conservation features, make the site selection very flexible in terms of finding efficient solutions. Most planning units are potential candidates to be included in the portfolio, and targets are very easy to reach. In this type of analysis, the suitability of individual planning units is the main factor determining spatial selection. If more species information was included, the site selection problem would increase and targets would be much more difficult to reach, and so flexibility decreased. Areas that are important for several or many conservation features would then be identified.

All minimum representation targets were met in all the scenarios presented here. Several features were also over-represented, meaning that more than the minimum representation target was captured. Since all scenarios contain rather few overlapping features, it can be assumed that most of the over-representation of features is due to criteria for spatial arrangement of the portfolio; i.e. the best portfolio for the 20 percent representation scenario corresponded to 20 percent of the total area when no sites were locked in, whereas as much as 30 percent of the total area was required when existing SACs were locked in to the network.

Table 3. The number of planning units selected, and the corresponding area in all scenarios.

SACs locked in	Total nr. Total Area selected of pu's			Selected Area in Percent of Total Study Area
20% scenario	13034	11505939 Ha	4391 pu's locked in 8643 pu's selected	27
10% scenario	8645	7311813 Ha	4391 pu's locked in 4254 pu's selected	17
30% scenario	15719	14406399 Ha	4391 pu's locked in 11328 pu's selected	33
SACs not locked in				
20% scenario	8990	8733550 Ha	No planning units locked in	20
SACs and SPAs locked in				
20% scenario	12926	11719687 Ha	4743 pu's locked in 8183 pu's selected	27

A network of MPAs selected site by site risks missing some habitats and species and over representing others, thereby producing a network of protected areas that is spatially inefficient in addition to representatively inadequate. Instead, the use of tools such as MARXAN provides support to identify an efficient and comprehensive network that is driven by and satisfies a number of quantitative ecological, and socio-economic goals. Using a transparent process, the analysis is repeatable and objective. Several different scenarios and solutions can be produced. In this analysis, only representation, and to a certain extent, replication (via stratification and the clumping parameter used) was considered. Technically, there are different ways to include the other coherence criteria into MARXAN. As discussed in earlier chapters there is, however, still little theoretical understanding of the concepts behind coherence, especially in the broad scale ecosystem context and it was not a reasonable alternative to include any detailed feature specific criteria for connectivity or adequacy in this analysis setup.

Recommended actions for establishing a representative network:

1. If the aim is to establish a representative network, we *strongly recommend* the use of a systematic approach to site selection instead of selecting MPAs site by site. A regional systematic approach maximizes the chance of creating a network that is representative and protects the whole range of biodiversity in the region.
2. Decision support tools for site selection provide support to identify a spatially efficient network that is driven by quantitative criteria using a transparent and repeatable process.

The results presented in this report should be viewed as a first step towards identifying a regional network of marine protected areas where the selection of sites is systematic and transparent, driven by quantitative conservation criteria and coordinated transnationally in the region. We have demonstrated the approach using a number of target levels and broad scale landscape data. The challenge to define precise criteria for a network remains though.

We have also shown how the method can be improved when more habitat, species and socio-economic data becomes available. The need for further mapping and investigation of the marine environment can not be emphasised enough. The access and availability of spatial data has to be further improved. Otherwise it is difficult to select a network of sites representing the whole range of biodiversity in the Baltic Sea, and thereby to implement the political directives and international agreements. Highest priority should be placed on activities such as improving data on the Natura 2000 habitats, rare and threatened species and habitat forming species (e.g. blue mussel, bladder wrack, eel grass, kelp etc), and also on the quality of different habitats and landscapes. Habitats that are of good quality can support more viable populations and make the ecosystem as a whole more resilient to pressure e.g. climate change. Oxygen depletion is one of the most important aspects of habitat quality in the Baltic Sea. Extensive areas in the Baltic Sea suffer from oxygen depletion and are thereby unsuitable habitats for a range of species. This assessment illustrates that a re-

gional systematic approach to site selection is indeed feasible in a multinational area such as the Baltic Sea Region.

Box 4. Case Study BALANCE Pilot Area 3 Swedish Archipelago – Åland – Archipelago Sea

The aim of the case study was to show how the regional broad scale assessment could be vastly improved with access to more detailed biodiversity data. Pilot area 3 has been the focus for other activities in the BALANCE project such as modelling of Natura 2000 habitats and fish recruitment areas and an assessment of the Natura 2000 networks' ecological coherence. More specific data was therefore available in this area in comparison to most other parts of the Baltic Sea.

The same set up of coarse and fine filter features used in the regional assessment, was used in the pilot area case study, with the exception of the additional fine filter features listed below. These are all data which have been developed within the BALANCE project.

Natura 2000 habitats; Estuaries (1130), Coastal lagoons (1150*), Large shallow inlets and bays (1160), Reefs (1170), Esker islands (1610) and Boreal Baltic islets and small islands (1620). (BALANCE Interim Report no 20)

Fish recruitment areas; Spawning habitats Perch (*Perca fluviatilis*) Nursery habitats Pike (*Esox lucius*), Roach (*Rutilus rutilus*) and Sander (*Sander lucioperca*). (BALANCE Interim Report no 11)

Areas predicted to have high heterogeneity were used to indicate areas with potential ecological "hot spots" (BALANCE Interim Report no 28).

The targets of 20 percent and 60 percent (for Natura 2000 priority habitats and species*) coverage of each Natura 2000 habitat (used as a guiding principle for sufficient protection when evaluating the EU-member states contribution to the Natura 2000 network), were used as the recommended minimum representation targets for all features in this assessment. It should be noted that only 18 of 60 benthic marine landscape types in the Baltic Sea occur within pilot area 3.

The framework for determining criteria for the spatial configuration of the network used in the landscape scale assessment was also used when determining principles for the pilot area assessment. For more details see BALANCE Interim Report no 24. The best portfolio and the summed solution are presented in Figure 11 below.

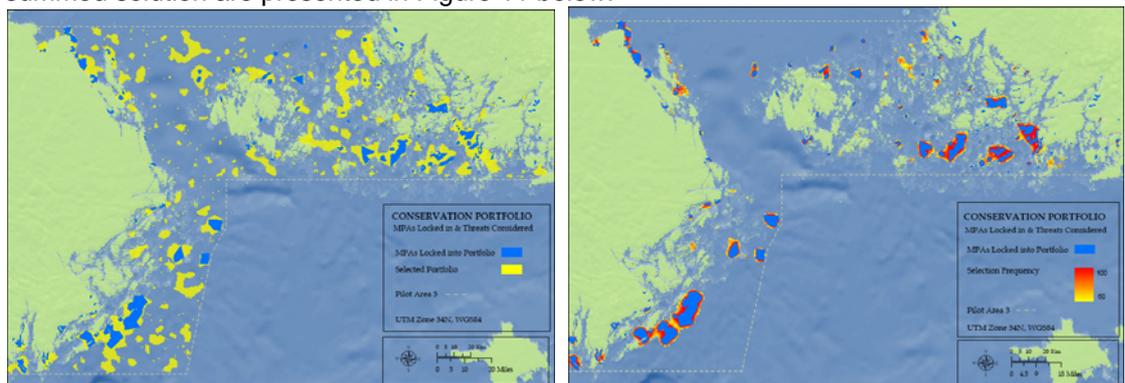


Figure 11. Map on the left: MARXAN "best portfolio" Map on the right MARXAN "summed solution"
 The portfolio represents a minimum of 20 percent of all benthic marine landscapes and 20 percent of the marine Natura 2000 habitats (non-priority habitats), 20 percent of each of the fish recruitment areas and 20 percent of the important bird areas occurring within the pilot area. Included are also 60 percent of the Natura 2000 priority habitat: Coastal lagoons and 60 percent of the Natura 2000 priority species: Grey Seal (Haul Out sites). The portfolio adds complementary sites to Natura 2000 SACs, using BLM=0.25 and a measure of suitability. The selection was done using simulated annealing with iterative improvement using 4 million iterations in 100 runs and CFPF-value 100 for all features. All targets were met.

* Natura 2000 priority habitats and species

5 TOWARDS ECOLOGICAL COHERENCE OF A BALTIC SEA MPA NETWORK: SUMMARY AND CONCLUSIONS.

MPA networks are composed of individual sites that are physically discrete and may have separate management structures and regimes, but that are interlinked and together meet objectives that single sites cannot achieve on their own. Many international agreements require *ecologically coherent* networks of protected areas. In order to function as an ecologically coherent network, MPAs need to (1) cover a proportion of all biotopes and habitats in the region, (2) be of adequate size, shape and quality to support the protected features, (3) be close enough to each other to ensure dispersal of species between the areas, and (4) contain replicates of protected features to provide insurance against catastrophic events and to ensure natural variation of the features. The four criteria (representation, adequacy, connectivity and replication) together form the concept of *ecological coherence* of protected areas.

In this part of the BALANCE project we have assessed existing MPA networks (in particular Natura 2000) in the Baltic Sea, Kattegat and Skagerrak, identified gaps, and proposed how to improve the coherence of the network. We have used a number of existing methods, and at times developed them further to suit the special conditions of the Baltic Sea region. We have also shown how the connectivity of a network can be assessed and planned for using existing ecological data on habitat preferences and migration, or using available data on larval duration in combination with oceanographic data through modelling. The representativeness, replication and adequacy was assessed with GIS and statistical analyses of geographical data, and the decision support tool MARXAN was used to formulate scenarios on how to improve the representativeness of the network.

Our assessment showed that the marine Natura 2000 network of Special Areas of Conservation (SACs) in the Baltic Sea is not ecologically coherent, given the criteria and methods defined within the BALANCE project. The network needs to be further improved to meet international conventions and agreements.

We recommend a **systematic approach** to develop a coherent network of MPAs, to ensure a transparent, repeatable and objective process. This underlies the choice of tools used in the project. Computer-based analyses with GIS, MARXAN, and the use of a specified flow scheme for connectivity assessment, may all contribute to the transparency of the process, and makes it possible to present the consequences of different "scenarios". The ability to present different scenarios is especially important when considering a network of MPAs rather than single MPAs, as it allows consideration of other user interests at an early stage, so that unnecessary conflicts can be minimised or avoided without compromising the broad scale conservation targets and objectives. It could therefore be linked directly to a transnational and cross-sectoral marine spatial planning approach.

We also recommend a **regional approach**. Transnational coordination will maximise the chance of designing a network of sites that fulfil all necessary criteria. This includes the characteristics of each site such as the size, location, purpose and relation to other sites, being designed with respect to all other sites in the network, including sites in other countries in the region. Since all nine countries involved are bound to the same international agreements and conventions, a joint regional approach would be the only reasonable way forward.

Although the analyses of different features of coherence within the BALANCE project were hampered by the lack of detailed ecological knowledge and goal formulations, the analyses still generated valuable information. Both the methods and the ecological knowledge need to be continuously improved, but rather than waiting for complete knowledge we suggest using what is available today. As long as there are obvious gaps in the network, even slightly crude methods can aid us in acting on the current knowledge. There are, however, a number of issues that should be improved:

- 1) Better ecological knowledge, e.g. how much needs to be protected, what are the migration distances etc.
- 2) Research programmes for collection of new data are needed such as the mapping of ecological and physical features and of human use. Existing data must be made more readily available.
- 3) Clearer formulations of goals, targets, and criteria both for individual MPAs and a network of MPAs are necessary. Such criteria and goals should be agreed upon in an appropriate political / management setting, and should be practical and applicable.
- 4) The Natura 2000 network is an important step towards creating a coherent MPA network in the Baltic Sea, but as the Habitat Directive is formulated today, it only covers part of the biodiversity values in existence in the Baltic Sea. To create a truly representative MPA network in the Baltic Sea, the range of species and of habitats included in the directive needs to be improved, to incorporate, for example, deep soft bottoms. Other frameworks need to be further developed to complement Natura 2000, such as the network of Baltic Sea Protected Areas (BSPAs).
- 5) An important aspect of adequacy is, of course, effective management. In our analyses, we have not assessed this: rather we assume that a Natura 2000 site is effective once it is formed. Methods to assess the quality of an area and the quality of management should be assessed and incorporated in future site selection and coherence assessments.
- 6) Connectivity among areas may be symmetrical, or some areas may contribute more to the export of individuals among the entire network. Therefore, incorporating analyses of direction in the coherence analysis will be important.
- 7) In the “real world”, socio-economic and political values have profound influences on site selection. The methods used in the BALANCE project have the

ability to incorporate such values and, with more complete data sets, more efficient multiple objective approaches are possible.

8) MPAs are a tool in an overarching spatial planning and management process and should be used together with other management tools. Many interests compete for marine space, and robust marine spatial planning will probably include management of several classes of areas (including large-scale sectorial regulations).

Finally, MPA network planning is an adaptive process, which needs to be continuously improved. Although socio-economic aspects are taken into account in the assessment and site selection methods used in the BALANCE project, establishing a network of marine protected areas involves more steps than assessing and selecting a set of candidate sites. These include: negotiations with stakeholders, revised selection of sites according to newly gained information and input, development of management and zoning plans etc. Therefore, the results from assessments and site selection proposals should always be seen as a first step in the process: a starting point for further negotiations.

We hope that this report will inspire governments, managers and stakeholders to participate in such a systematic conservation approach to implement international obligations.

6 ACKNOWLEDGEMENTS

We wish to thank all BALANCE partners and external expertise contributing to the work done within work package 3, including participants in the BALANCE WP3 Workshops: ‘Selecting representative MPA networks using decision support tools’ 15-16 September 2005, Stockholm; ‘Ecological Coherence and Representative MPA networks’ 28-29 March 2007, Helsinki; ‘Ecologically Coherent Network of Marine Protected Areas in the Baltic Sea and North East Atlantic. HELCOM-BALANCE Workshop, 25-27 October 2006, Helsinki.

We also wish to thank partners in work package 1, 2 and 4 for good cooperation throughout the project.

7 LITERATURE CITED

In this report we have chosen not to include the complete reference list. For a more in-depth coverage of the issues discussed here, including literature references, see the following BALANCE Work Package 3 Interim Reports:

BALANCE Report no 2: Andersson, Å. and Liman, A-S. (eds) 2005. Development of a methodology for selection and assessment of a representative MPA network in the Baltic Sea. An interim strategy.

BALANCE Interim Report no. 4: Martin, G. (ed). 2006. Literature review of “blue corridors” concept applicable to the Baltic Sea conditions.

BALANCE Interim Report no 9: Bendtsen, J., Söderqvist, J., Dahl, K., Hansen, J.L.S. and Reker, J. 2007. Model simulations of blue corridors in the Baltic Sea.

BALANCE Interim Report no. 18 Nilsson P. and Martin G. (eds.) 2007. A practical guide on application of blue corridor concept on MPAs for biodiversity conservation in the Baltic Sea.

BALANCE Interim Report no. 24. Liman, A-S., Andersson, Å. and Huggins, A. 2007. Towards selecting a representative network of marine protected areas in the Baltic Sea.

BALANCE Interim Report no. 25. Piekäinen H and Korpinen S (eds.) 2007. Towards an Assessment of ecological coherence of the marine protected areas network in the Baltic Sea region.

BALANCE Interim Report no 29. Bergström, L. (ed). 2007. Essential fish habitats and fish migration patterns in the northern Baltic Sea.

The following BALANCE reports are also related to the work done within WP3:

BALANCE Interim Report no 10. Al-Hamdani, Z. and Reker, J. (eds). 2007. Towards marine landscapes in the Baltic Sea.

BALANCE Interim Report no. 11 Bergström, U., Sandström, A., Sundblad, G. 2007. Fish habitat modelling in the Archipelago Sea.

BALANCE Interim Report no. 27: Dinesen, G.E, Skov, H. and Reker, J. (eds). 2007. Mapping and modelling of marine habitats in the Baltic Sea ecoregion.

BALANCE Interim Report no. 28: Snickars and Pitkänen. 2007. GIS tools for marine spatial planning in the Baltic Sea..

These and other reports from the BALANCE project can be downloaded from the BALANCE web site <http://balance-eu.org>



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 is 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.

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For more information on BALANCE, please see www.balance-eu.org and for the BSR INTERREG Neighbourhood Programme, please see www.bsrinterreg.net.

